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MAST Information on methods and subjects.

OT Oceanographic data.

IT Limnological data.

and

CART Information concerning fisheries and resources of certain countries and regions (FID/S).

SAST Données sur certaines espèces et populations de poissons.

MAST Renseignements sur des méthodes et des sujets.

OT Données océanographiques.

IT Données limnologiques.

et

CART Renseignements sur les pêcheries et les ressources de certains pays et régions (FID/S).

SAST Datos relativos a ciertas especies y poblaciones.

MAST Sinopsis sobre métodos y materias.

OT Sinopsis sobre oceanografía.

IT Sinopsis sobre limnología.

y

CART Información sobre los recursos acuáticos vivos de algunos países y regiones (FID/S).

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RE Indexed lists of experts and institutions drawn from Registers maintained by the Fishery Resources Division.

CB Lists of periodicals, special sections of " Current Bibliography for Aquatic Sciences and Fisheries," special bibliographies and papers concerning documentation problems.

MFS Provisional editions of " FAO Manuals in Fisheries Science."

RE Listes indexées d'experts et institutions tirées des registres tenus à jour par la Division des ressources halieutiques.

CB Listes de périodiques, des sections spéciales de la « Current Bibliography for Aquatic Sciences and Fisheries», des bibliographies particulières et des articles sur les problèmes de documentation.

MFS Editions provisoires des «Manuels FAO de science halieutique ».

RE Listas índices de expertos y de instituciones tomadas de los registros que se llevan en la Dirección de Recursos Pesqueros.

CB Listas de periódicos, secciones especiales de la « Current Bibliography for Aquatic Sciences and Fisheries», bibliografías especiales y trabajos relativos a los problemas de documentación.

MFS Ediciones provisionales de los « Manuales de la FAO de Ciencias

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FAO Fisheries Technical Paper No. 102
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FIRM/T102
NFS - Fisheries Resource Survey

MANUAL OF METHODS FOR FISHERIES RESOURCE SURVEY AND APPRAISAL

PART 1. SURVEY AND CHARTING OF FISHERIES RESOURCES

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PREPARATION OF THIS DOCUMENT

This publication is one of a series of FAO "Manuals in Fisheries Science". It is based on the Report of the Advisory Committee on Marine Resources Research (ACMRR) Working Party on the Methodology of Survey and Charting of Fishery Resources, of which the editor was convener. The other members of the Working Party were Dr. N. Andreev, U.S.S.R., Dr. D.H. Cushing, U.K., Mr. C. Nedelec, France, Dr. L.M. Dickie, Canada, Dr. T. Matsushita, Japan, and Mr. S. Olsen, FAO (Technical Secretary).

The present provisional version has been reproduced primarily for use at FAO and associated training centres, in FAO field projects and for limited distribution to specialists, on the basis of whose comments it is planned a revised edition will eventually be published in the official languages of FAO. The final revision will take into account experiences in the use of the present version for training purposes, and will incorporate further advances in this field of research.

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Fisheries resources survey - abundance and potentialities. Techniques, equipment, evaluation of data. Forecasting of fisheries potentials - indirect methods. Exploratory fishing. Acoustic surveys - estimation of relative and absolute abundance of fish - echo counting information. Data collection and recording - analysis and reporting - interpretation of results. Examples of different regions and species. Selected bibliography. Technical glossary.

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1. INTRODUCTION

Since the end of the second world war there has been increased interest in the potential food resources of the oceans. The beginning of this interest was marked by a rapid rebuilding of fishing fleets in the more developed countries which subsequently returned to traditional fishing grounds. However, increasing product demand out-paced the yield potential from the old grounds, leading to an expansion into new geographic areas and exploitation of hitherto unused species. This expansion was often accompanied by the introduction of new types of fishing gear. At the same time, the developing nations became increasingly interested in the ocean's living resources as a source of protein foods to supply domestic needs or for earning foreign currency.

Initially, expansion of fishing areas was frequently based on relatively simple information. Some of it depended on the initiative shown by individual vessel owners or nations taking advantage of casual observations made in the course of other fishing activities. Other fleets extended their operations as a result of scouting activities conducted aboard vessels sent into unfished areas. These areas presumably appeared promising on the basis of the apparent similarity of their hydrographic or topographic characteristics with known fishing grounds.

Increasingly, new areas and resources have been put into production. New fishing developments are more and more dependent on smaller differences between the catch rates and the value of catch possible in various areas. Thus, the quality of information about the community of fish and shellfish available in unexploited regions has become more important for judging their fisheries development potentials.

These increased requirements for better information on the available resource demands a more careful and systematic approach to fishery surveys than before. There is still room for the purely exploratory survey, designed primarily to detect unusual availability. However, with the present large and highly mobile world fishing fleets, it is now essential to gauge not only the immediate availability of a new resource, but to obtain information on the stock abundance, and biological and environmental information which will permit a preliminary judgement of longer-term yield prospects. In this sense, the resource survey must be treated as an integral part of the overall problem of resource development.

Studies of marine production having the objective of increasing the use of the living resources of the sea may be termed resource assessment (Gulland, 1969). In fisheries jargon resource assessment has been commonly attributed to studies on the status of fish stocks subjected to exploitation (stock assessment). In a broader context, resource assessment also includes studies of the availability, distribution, abundance and yield potentials of latent or little-used resources and this wider definition has been applied in preparing this manual on fishery resource surveys.

Results of fishery surveys can be inconclusive, difficult to interpret, and/or misleading unless properly planned. In this sense, they may be a deterrent to development rather than being helpful. Unfortunately, the history of exploratory fishing is rich in examples of poorly planned and poorly executed surveys with correspondingly poor information output. Such activities have at times provided data which were rather misleading or quite unreliable for planning fishing activities and useless for formulating management policies. When properly planned, fisheries charting and surveying can provide useful information on:

(1) the community of fish available in a specific geographic area;

(2) their distribution in time and space;

(3) the magnitude of the exploitable portion of the stock;

(4) yield potentials which may be anticipated;

(5) feasibility of commercial exploitation;

(6) fishing strategy required, and thereby provide the basis for development of an ultimate management rationale.

Assessment of fisheries potential is the starting point for obtaining information upon which industry can design and plan expanded operations and upon which government can acquire the necessary preliminary information for ultimate management of such resources. The design of resource assessment projects should therefore be considered in the light of existing resources demands and economic problems confronting their utilization. However, the design must not be restricted to the satisfaction of immediate needs. It must provide the maximum possible information on the totality of aquatic resources having current or future potential to supply man's needs and natural factors influencing their availability.

Experience makes obvious the need to improve fisheries surveys through greater use of available oceanographic data. Oceanographic surveys conducted in the past several decades have closed major gaps in the knowledge of large scale circulation and biological patterns in the world ocean. This background information provides valuable data that should be evaluated when planning and executing fisheries surveys. The production of fishes on both the continental shelf and in the open ocean is generally closely related to regions of mixing, upwelling, or surface convergence or to oceanographic fronts or barriers which mark the migratory routes or regions of fish aggregations. Fisheries surveys need no longer be made in isolation from a knowledge of physical oceanographic features which characterize most areas. In addition, the knowledge of water quality requirements of various species such as tunas makes it possible to be quite selective in the choice of areas appropriate for surveys. For this reason, in what follows, acquisition and/or interpretation of oceanographic data is considered an important aspect of fisheries resource surveys. Knowledge of oceanographic situations and bottom topography should form an integral part of the background data used in planning tracklines and sampling strategy.

The major cost of fisheries resource surveys is the vessel and its equipment. With the understandable concern of the administrator to get the most for his money, it is unfortunate that the purpose of the exercise, which is to produce a report which can provide a firm foundation for predictions, seems often to be neglected. The survey is as good as the information collected and the quality of the analysis and reporting. This, in most cases, will involve the processing and interpretation of a considerable data array. It must be stressed at the outset that optimal use of information to be collected requires consideration of the needs of data analysis and reporting at every stage of planning. This implies that the data processors must form part of the planning team. Unless the administrative planner makes provision for data processing and analysis in setting up the financial plans for the survey, there can be no guarantee that the results of a survey can be associated with future work, or even that the survey itself may not have to be repeated for want of essential information. These considerations underlie the proposals for design of survey and data collection and processing which are made throughout this manual.

2. INDIRECT METHODS FOR FORECASTING FISHERIES POTENTIALS

In the past 20 years, rapid strides have been made in our understanding of what is in the oceans, and its potential for providing needed protein. This knowledge has been derived in spite of the fact that observational techniques are far from perfect. Concepts of the ocean's potential to provide food have come from:

(1) estimates based on the general productivity of the oceans or certain sectors of the oceans;

(2) observations on the distribution and abundance of eggs and larvae of certain fish and shellfish;

(3) inferences made by examining the stomach contents of larger fish or mammals, or the activities of sea birds;

(4) direct observations on the numbers and types of schools of fish appearing near the ocean's surface (aircraft or shipboard) or in subsurface waters using submersibles, skin divers, etc;

(5) systematic sampling with large fishing gears;

(6) acoustic surveys;

(7) extrapolation from known areas.

Thus, a variety of methods have been employed to gather information on the general productivity of the oceans or on the specific availability and abundance of certain animals or communities of animals which inhabit the seas. A cursory review of assessment methods which are based on an understanding of the forage base used by the higher trophic forms of current commercial interest is given in this chapter. More detailed accounts of the methodology for direct surveying and charting of fishery resources are given in subsequent chapters.

2.1 Basic productivity

The general productivity of the ocean can be determined by measuring certain physiological processes or by evaluating standing stocks of phytoplankton. Productivity in the oceans is often evaluated by taking samples of water collected from specific locations and depths and measuring changes of certain non-conservative properties at the start and end of some specified culture period. The two most commonly employed techniques include evaluation of oxygen production and C-14 uptake.

Until recently, measure of oxygen production was the most widely employed method used in measuring plant activity or metabolism. It is based on the fact that during photosynthesis oxygen is produced proportionately to quantities of carbon assimilated; and that during this process, relative amounts of CO_2 and oxygen will be assimilated and released (Steeman-Nielson, 1963).

Radioactive C-14 is now commonly employed for measuring plant productivity. The technique is not over-complicated, although a certain amount of familiarity with tracer work is necessary for the preparation of C-14 ampoules used in measuring radioactivity.

An index of productivity can also be derived by determining the quantity of plankton per volume of water sampled (standing stock). Concentrations or quantity of pigments which are active in the process of photosynthesis (primarily chlorophyll) can also be measured and used as an index of standing stock. In this case, samples of water are taken, the pigments extracted in acetone, and the quantities of chlorophyll contained in them measured. Both of the above methods characterize standing stock estimation and although some investigators have attempted to use the amounts of chlorophyll available in phytoplankton to estimate productivity, the technique does not appear to be as reliable as the oxygen or the C-14 method.

Several authors have forecasted fish potentials based on primary productivity figures (Graham and Edwards, 1962; Schaefers and Alverson, 1969; Ryther, 1969; Ricker, 1969). Such estimates based on the flow of material through the food chain involves three primary considerations: The amount of carbon fixed annually; efficiency with which nature transfers material up through the food chain, and the trophic level at which to calculate fish production or yields. Apart from the uncertainty surrounding the total oceanic carbon fixation, such estimates are based on the assumption that the complex and variable food web in the sea can be treated as a simple chain of trophic levels and that fish production can be assigned to a specific level in the chain; that it is possible to reduce the transfer of material from predator to prey to a single set of values representing ecological efficiency; and on a guess as to the percentage of production available to man.

Estimates using this procedure are extremely sensitive to the values assigned these parameters. The choice between two adjacent levels involves a possible error of an order of magnitude or more depending on the "ecological efficiency" factor chosen. The choice within a given range of ecological efficiency may involve an error of a similar order depending on ecological transfer efficiency values used. Ignoring other sources of uncertainty such estimates can therefore easily be wrong in either direction by a factor as large as 1-2 orders of magnitude (Alverson, _et al._, 1970).

Despite the problems involved, the forecast of ocean potential based on primary productions are of value in considering the amount of food that might be available for various levels of the food chain. Table 1 shows estimates of the annual net fixation of carbon (total world oceans) by phytoplankton and the quantity both in terms of carbon and net weight available to predation at various trophic levels above plants. Ecological efficiency factors (maximum sustainable rates of transfer between levels) of 10, 15, and 20 percent were applied. Thus, from Table 1 we can get some concept of the potential production at each trophic level.

Table 1. Estimates of potential yields 1/ (per year) at various trophic levels, in metric tons*

Trophic level	Ecological efficiency factor 10%		15%		20%	
	Carbon	Total wt	Carbon	Total wt	Carbon	Total wt
(0) Phytoplankton (net particulate production)	1.9×10^{10}		1.9×10^{10}		1.9×10^{10}	
(1) Herbivores	1.9×10^{9}	1.9×10^{10}	2.8×10^{9}	2.8×10^{10}	3.8×10^{9}	3.8×10^{10}
(2) 1st stage carnivores	1.9×10^{8}	1.9x109	4.2×10^{8}	4.2×10^{9}	7.6×10^{8}	7.6×10^{9}
(3) 2nd stage carnivores	1.9×10^{7}	1.9×10^{8}	6.4×10^{7}	6.4×10^{8}	15.2×10^{7}	15.2×10^{8}
(4) 3rd stage carnivores	1.9×10^{6}	1.9×10^{7}	9.6×10^{6}	9.6×10^{7}	30.4×10^{6}	30.4×10^{7}

1/ Output to predation at each trophic level.

* From Schaefer, M.B., 1968, Trans.Am.Fish.Soc., Vol.94, No. 2, P.127.

Potential fisheries production from a region can be defined as the harvest which can be taken by man (as a predator) on a continuing basis operating at a given trophic level or combinations thereof. It is obvious, however, that for some trophic levels and species man cannot, because of economic limitations, feasibly harvest all materials available to predation. Actual fisheries potentials must be that share of the flux of material through the food web which can be actually removed by man on a sustained basis. This, of course, will depend on the potential productivity and the state of technology (Schaefer and Alverson, 1968).

The advantage of using primary productivity in forecasting fisheries production from large areas of the sea is related to the cost of primary surveys. It is relatively cheap to take large numbers of water samples and calculate primary productivity while, in general, it would be much more costly to obtain a total measure of the complex of higher organisms generally used in fisheries. Indeed, with some of the larger nekton the present limits of sampling gear preclude reliable results.

The major disadvantage of using basic production values in determining fisheries potential relates to the large number of unknowns involved in making such forecasts. In addition, such forecasts provide nothing in the way of usable information on planning fisheries as there is no specific information as to the identification of important exploitable elements or where they may be found in the system; that is, they do not answer the question of what types and in what quantities commercially exploitable fishes occur and whether or not they are susceptible to harvest with existing fishing methods.

Such estimates may also be directly misleading in terms of fishery potential. Thus, fish or shellfish may occur in very low concentrations (density) and still form the basis of a substantial commercial fishery. This only requires that the product value is high and/or the extractive technology is highly efficient. Similarly, areas of basically low ocean productivity may have a high flux of usable fish in transit to other areas, and thus could become productive fishing grounds.

2.2 Forecasts from zoo-plankton abundance

Abundance of higher marine forms is often related to the standing stock of zoo-plankton. Standing stocks of zoo-plankton can be measured using a variety of gears.

Plankton nets are generally very selective (depending on mesh size) and no one net can yield a zoo-plankton sample in a manner that the relative abundance of animals can be calculated one against the other. By modifying the mesh size in the net, one can effectively strain out certain portions of the zoo-plankton available. Unfortunately, if one uses the finest mesh sizes available to enable the capture of the minutest zoo-plankton (protozoans, etc.), the net is not effective for capturing larger zoo-plankton (euphausiids). Therefore, a variety of net sizes is generally used, depending on the sizes of zoo-plankton one wishes to sample.

For the larger zoo-plankton, rigid midwater trawls such as the Isaac-Kidd have been developed. All of these gears present certain problems to an investigation attempting to make quantitative assessments of the biomass of animals inhabiting a certain water volume strained, and in establishing where the animals were taken in the water column. Until recent years, no methods were available to open and close the large plankton nets; hence, they began fishing as soon as they entered the water and fished through the water as far as the net descended. Upon retrieval, one had to calculate the time spent at various depth intervals and "weight" the zoo-plankton samples accordingly.

More sophisticated gears have recently been developed which allow opening and closing the plankton net on command from the ship. These devices have allowed one to obtain a better understanding of the bathymetric distribution of zoo-plankton. The zoo-plankton productivity - that is, the amount of new material being produced per unit of time - has been more difficult to calculate and is largely based on laboratory studies. As zoo-plankton vary greatly in size, form, and longevity, it is more difficult to make specific statements concerning annual productivity of this complex of organisms, particularly when standing stocks of all segments of the community are not easily established. In fact, we do not have any satisfactory measures of zoo-plankton production.

Standing stocks of some of the more important zoo-plankton forms are, however, commonly estimated and used to index the relative availability of forage items for larger fish and shellfish. It cannot reasonably be concluded, however, that the large number of zoo-plankton surveys conducted throughout the world during the past 50 years have added appreciably to our knowledge of exploited or latent resources of fish and shellfish stocks. Catalogues of zoo-plankton distribution which have been compiled, however, may be quite useful in man's future exploitation of the sea, particularly if new technology makes it possible to utilize the larger zoo-plankton forms. Continued studies of zoo-plankton populations should also provide a better understanding of the energetics of the food web; and, hence, improve forecasts of potential fish production based on primary productivity.

2.3 Egg and larva surveys

Enumeration of eggs and larvae as a means of estimating adult fish populations was begun well over half a century ago. Its concept is relatively simple. If the total number of eggs spawned in a season can be estimated and the mean fecundity determined, and finally, if one knows the percentage of females to males in the stock, then the abundance of the mature stock can be calculated.

Saville (1963) has written an excellent review on estimating the abundance of fish stocks from egg and larvae surveys. He quantifies the mature stock using the equation $M = \frac{P}{KF}$ where P = the total production of eggs or larvae of a stock; F = the mean fecundity of the mature female population; and K = the proportion of females in the stock. If the spawning stock surveyed does not represent the total exploited stock, the latter can be determined from a knowledge of the relative proportions of mature and immature fish in the commercial catches. Saville points out that before an attempt is made to estimate populations based on egg and larva surveys, certain basic features of spawning biology of the stock in question must be adequately known. First, it is essential that one be able to identify the spawning products; and, hence, eliminate the possibility that the sample will be contaminated with eggs or larvae from other species. In addition, a knowledge of the extent of the spawning area and the period of time over which spawning takes place is necessary to form the basis of an adequate sampling programme. Finally, the rate of development over the range of temperatures encountered in the survey area during the spawning season must be determined.

The statistical aspects have been well described by English (1964) though it should be noted that his data were derived from an area with a rather complex hydrographic structure, and probably the variances he found are higher than usually found elsewhere.

The advantages of the egg and larva surveys relate principally to ease of collection. Obviously, eggs and most larvae are not capable of active gear avoidance. Hence, if one can devise an effective sampling pattern, it should be possible to derive fair estimates of the abundance of important elements in the particular oceanic region for pelagic eggs, and of the abundance of specific benthic spawners.

A disadvantage in terms of useful fishing information of the egg and larvae survey relates to the fact that the distribution of eggs and larvae may have little relationship to the distribution of the adult stock during a large part of the year. This, of course, does not detract from quantitative data acquired; but unless considerable other biological information is known, it may give a false impression of the geographic extent or habitat of the stocks surveyed. Egg and larvae surveys are therefore of limited value in planning fishing and harvest strategy, although they may be of value in determining anticipated yields in specific cases. Even abundance may be difficult to interpret in terms of the total area occupied by the species; that is, if egg and larva surveys do not cover the total spawning zone of the species in question. Finally, sampling problems and difficulties in establishing fecundity for species that spawn more than once each year make results questionable or at the best, very unprecise. Nevertheless, collection of eggs and larvae data have and can provide clues as to latent fisheries resources, their collection as a part of oceanographic surveys, and broadly oriented studies of biological productivity should be encouraged. However, if it is a question of carrying out a survey solely or mainly for fishing purposes, an egg and larva survey is likely to be less useful from the standpoint of information for a given cost than the more direct fishing or acoustic survey described later.

Because they are easy to catch and their main distribution area is usually limited and fairly well defined, it is generally much simpler to sample the distribution and abundance of the young fish fry or fingerlings than of the adults. Young fish surveys with special-fine meshed gear, sometimes combined with acoustic surveys, have therefore proved useful for the purpose of forecasting subsequent stock size changes due to fluctuations in year-class strength. Such surveys could also provide provisional estimates of the magnitude of the commercially-exploitable stock in new unfished areas if reasonable assumptions about the level of natural mortality in the pre-exploitable phase can be made.

2.4 Examinations of stomachs - higher trophic forms

A good deal of information about what lives in the ocean has been gleaned from studies of feeding patterns of larger fishes and mammals. Most often, these creatures seem to be better fishermen than men; and from examination of their stomachs, it has been possible to determine the small fish and fauna available in a region. For example, a detailed investigation of the fur seal feeding patterns in the waters of the northeast Pacific provided some rather interesting results. The data showed that off California the dominant food items included hake, anchovies, and sardines; off Washington the primary food was Pacific hake; and off British Columbia herring, lanternfish, and other species predominated (Wilke and Kenyon, 1954). A rather interesting aspect of this work was that it predicted rather well the current scientific viewpoint as to some of the more abundant marine fishes inhabiting these areas.

Food studies can provide vital information on the food base on which the larger forms subsist and subsequent fisheries investigations have ultimately found these items to be more abundant than was at first believed. The advantage of this system is that it is relatively cheap and can be a spin-off from other types of basic zoological investigations. The main disadvantage of food studies relates to our present inability to quantify the abundance of organisms taken from stomach samples. The question concerning the selectivity of the animal is also involved; that is, does the animal discriminate in its selection of food items or is it an opportunist, taking anything that is available. One might suspect that the sampling problems which affect our understanding of the capturing efficiency of certain gears must also apply to fish and mammals; that is, certain food items or lower forms are more effective at escaping these straining devices than are others.

More sophisticated gears have recently been developed which allow opening and closing the plankton net on command from the ship. These devices have allowed one to obtain a better understanding of the bathymetric distribution of zoo-plankton. The zoo-plankton productivity - that is, the amount of new material being produced per unit of time - has been more difficult to calculate and is largely based on laboratory studies. As zoo-plankton vary greatly in size, form, and longevity, it is more difficult to make specific statements concerning annual productivity of this complex of organisms, particularly when standing stocks of all segments of the community are not easily established. In fact, we do not have any satisfactory measures of zoo-plankton production.

Standing stocks of some of the more important zoo-plankton forms are, however, commonly estimated and used to index the relative availability of forage items for larger fish and shellfish. It cannot reasonably be concluded, however, that the large number of zoo-plankton surveys conducted throughout the world during the past 50 years have added appreciably to our knowledge of exploited or latent resources of fish and shellfish stocks. Catalogues of zoo-plankton distribution which have been compiled, however, may be quite useful in man's future exploitation of the sea, particularly if new technology makes it possible to utilize the larger zoo-plankton forms. Continued studies of zoo-plankton populations should also provide a better understanding of the energetics of the food web; and, hence, improve forecasts of potential fish production based on primary productivity.

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The statistical aspects have been well described by English (1964) though it should be noted that his data were derived from an area with a rather complex hydrographic structure, and probably the variances he found are higher than usually found elsewhere.

The advantages of the egg and larva surveys relate principally to ease of collection. Obviously, eggs and most larvae are not capable of active gear avoidance. Hence, if one can devise an effective sampling pattern, it should be possible to derive fair estimates of the abundance of important elements in the particular oceanic region for pelagic eggs, and of the abundance of specific benthic spawners.

A disadvantage in terms of useful fishing information of the egg and larvae survey relates to the fact that the distribution of eggs and larvae may have little relationship to the distribution of the adult stock during a large part of the year. This, of course, does not detract from quantitative data acquired; but unless considerable other biological information is known, it may give a false impression of the geographic extent or habitat of the stocks surveyed. Egg and larvae surveys are therefore of limited value in planning fishing and harvest strategy, although they may be of value in determining anticipated yields in specific cases. Even abundance may be difficult to interpret in terms of the total area occupied by the species; that is, if egg and larva surveys do not cover the total spawning zone of the species in question. Finally, sampling problems and difficulties in establishing fecundity for species that spawn more than once each year make results questionable or at the best, very unprecise. Nevertheless, collection of eggs and larvae data have and can provide clues as to latent fisheries resources, their collection as a part of oceanographic surveys, and broadly oriented studies of biological productivity should be encouraged. However, if it is a question of carrying out a survey solely or mainly for fishing purposes, an egg and larva survey is likely to be less useful from the standpoint of information for a given cost than the more direct fishing or acoustic survey described later.

Because they are easy to catch and their main distribution area is usually limited and fairly well defined, it is generally much simpler to sample the distribution and abundance of the young fish fry or fingerlings than of the adults. Young fish surveys with special-fine meshed gear, sometimes combined with acoustic surveys, have therefore proved useful for the purpose of forecasting subsequent stock size changes due to fluctuations in year-class strength. Such surveys could also provide provisional estimates of the magnitude of the commercially-exploitable stock in new unfished areas if reasonable assumptions about the level of natural mortality in the pre-exploitable phase can be made.

2.4 Examinations of stomachs - higher trophic forms

A good deal of information about what lives in the ocean has been gleaned from studies of feeding patterns of larger fishes and mammals. Most often, these creatures seem to be better fishermen than men; and from examination of their stomachs, it has been possible to determine the small fish and fauna available in a region. For example, a detailed investigation of the fur seal feeding patterns in the waters of the northeast Pacific provided some rather interesting results. The data showed that off California the dominant food items included hake, anchovies, and sardines; off Washington the primary food was Pacific hake; and off British Columbia herring, lanternfish, and other species predominated (Wilke and Kenyon, 1954). A rather interesting aspect of this work was that it predicted rather well the current scientific viewpoint as to some of the more abundant marine fishes inhabiting these areas.

Food studies can provide vital information on the food base on which the larger forms subsist and subsequent fisheries investigations have ultimately found these items to be more abundant than was at first believed. The advantage of this system is that it is relatively cheap and can be a spin-off from other types of basic zoological investigations. The main disadvantage of food studies relates to our present inability to quantify the abundance of organisms taken from stomach samples. The question concerning the selectivity of the animal is also involved; that is, does the animal discriminate in its selection of food items or is it an opportunist, taking anything that is available. One might suspect that the sampling problems which affect our understanding of the capturing efficiency of certain gears must also apply to fish and mammals; that is, certain food items or lower forms are more effective at escaping these straining devices than are others.

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3. EXPLORATORY FISHING SURVEYS

The term exploratory fishing is used here in the sense of a planned study by fishing gear of the fish resources inhabiting a defined area of the ocean. It is important here to differentiate exploratory fishing from resource assessment activities or gear experiments which are conducted to support on-going fishery activities, e.g.:

(1) fisheries monitoring - year-to-year and long-term studies of changes in the abundance of species;

(2) fisheries forecasting - pre-season forecasting based on preliminary assessment of the strength of incoming year classes (recruitment), or on the basis of environmental conditions;

(3) fisheries scouting - the use of research or commercial vessels to locate concentrations of commercial fish and disseminate such information to the commercial fishing fleet;

(4) experimental fishing - activities designed to explore the utility of various types of gear or fishing strategy to increase the efficiency of the extractive phase of a particular fishery.

Some of the difficulties in undertaking exploratory fishing relate to the design of a programme that will satisfy two primary data users - the commercial fishing industry (both the fishermen and the processor) and the scientific community. The scientific aim is to carry out a programme which will most effectively describe the community or complex of animals inhabiting a particular area and at the same time derive a fundamental understanding of spatial distribution, determine how distribution patterns change with time, and quantify as best as possible the various elements that constitute the fish and shellfish complex.

The objectives of the fishing industry are more restricted. Although the fisherman may also desire information on long-range forecasts covering the magnitude of the resource for investment planning, he is more immediately interested in the distributional and catching aspects, such as where the fish of commercial size aggregate, and their availability to his fishing gear. He wants to know how much he can catch in what period of time, where and how he should deploy his vessels to maximize the usable catch, and whether the anticipated catch is of sufficient value to justify his participation in the fishery. He is not as interested in the total bathymetric or geographic range of the species as he is in the bathymetric zone in which the fish tend to concentrate, the various densities of fish throughout this zone, and the seasonal distribution pattern of the exploitable stock.

The processor has a more specific need for general information on the seasonal geographic distribution of the stocks including areas and times of the year where maximum densities occur. He also will want to know the potential harvest and sizes of individuals from these stocks so he can plan his processing operation to maximize returns.

3.1 Operational limitations and facilities

In planning a fishery survey to investigate distribution and abundance of a potentially important fish or shellfish group, a variety of factors beyond those of a technical nature must be considered. To begin with, the investigator must take into account the terms of reference under which the surveys are to be conducted; that is, the restrictions imposed by the supporting government or international body. These restrictions may limit the survey area, the species to be surveyed, the time periods in which the survey may be conducted, and the manner in which the work will be conducted. Certain operational constraints are inherent, which for the most part are not subject to change by the investigators responsible for executing the field work.

Although it is expected that certain operational limits must be established by the supporting body, it is desirable that these terms relate only to the general goals of the study; e.g., (1) investigate the potentials of the south coast of Argentina, (2) investigate the shrimp potential in the Gulf of Guinea, (3) investigate the distribution and abundance of skipjack tunas in the mid-Pacific Ocean, or (4) study the clam potential within Cook Inlet, Alaska.

The methodology required to reach these goals should be established at the planning stage. If the programmes are rather tightly defined, as in item (4) above, the investigator will not have to concern himself with area selection other than that of a local nature.

Although general operational guidelines are frequently provided as above, more specific goals should be defined for individual cruises or sets of cruises. These goals should be clearly formulated in terms of specific questions about the resource being investigated; e.g., (1) what demersal fish inhabit a particular region and bathymetric range during a specified time period, (2) what catch rate can be achieved for a particular species with a specified sampling device in a certain area, (3) what sizes of fish are available on a seasonal and/or annual basis, (4) what behaviour or distribution patterns prevail that may effect use of the resource, and how are these patterns influenced by environmental factors, and (5) what is the magnitude of the defined resource and what yield potentials can be expected. The character of the questions and the priority for answering them must, of course, relate to the general programme goals.

Planning at the field level (within the general terms of reference given) must start with a consideration of the facilities and staff at one's disposal; that is, (1) level of programme funding, (2) number and competence of personnel, (3) time allocated, (4) physical facilities available, (5) survey methodology, and (6) local, legal, and operational problems. These factors will determine the character and size of programme that can be mounted. In this sense the question is not what is the most effective and logical manner to accomplish the mission, but what is the best plan considering the resources at one's disposal and the constraints. Adequate and intelligent planning will contribute to the success of a programme and to making optimal use of available manpower and equipment. It does not necessarily mean, however, that the job will be accomplished in a manner that will satisfactorily answer all the questions concerning the character of the resource being investigated.

It is important that one does not over-programme; that is, one should establish objectives and work plans that are realistic. If the objectives established by the supporting agencies are too ambitious relative to funds available, and if additional funding cannot be obtained, the investigator should consider other options; e.g.:

(1) narrow the objectives and limit the scope of observations to be made;

(2) consider cooperative possibilities with other agencies, academic institutions, governments, etc.

Finally, the field investigator should state clearly to the administrator just what he believes can be accomplished with physical facilities and funds at his disposal.

In choosing personnel to carry out the field studies it should be borne in mind that the character of personnel will, to a large degree, control the scope and quality of observations that can be effectively made. Fisheries resources surveys require investigators with a knowledge of the fauna in the area being investigated or ability to use taxonomic literature, experience in sampling animal populations and in making oceanographic observations. In addition, knowledge of using and interpreting echo sounder and sonar data and of fishing gears and their operation is essential. The field programme leader should be a competent scientist with a background in marine biology, experimental design, general field of oceanography, and have an analytical capability. However, success of the mission requires more than just scientific knowledge and technical skills. <u>It will also require a mixture of talents and experience in working and living at sea, at times on small boats in cramped quarters, and knowledge of design and use of fishing gears</u>.

3.2 Selection of species

If operational limits narrowly define the field to be investigated, establishment of work priorities among species, species groups, etc., may not require special attention. On the other hand, if the assignment given is general, e.g., investigate the fishing potential of a particular locality, a judgement has to be made concerning the order in which to survey certain species, ecological and taxonomic groups. For such a general type of assignment a number of factors must be evaluated. Important among these are:

(1) What information exists concerning the fauna of the region?

(2) What species are of local interest and use?

(3) Can adequate sampling systems be devised for species of interest and what are the logistic and operational problems?

(4) What factors limit the use of the several species once information on the resource base has been established?

For planning the fisheries surveys, it is helpful for the field investigators to make a brief compilation of information on distribution and behaviour of the same or related species in other areas where they are already extensively harvested. One example is given on southern bluefin tuna (see Appendix I). Such tables compile knowledge of the oceanographic features of one or more sea areas thought to be similar with the area to be surveyed. If little or no information exists concerning the nature of the local fish and shellfish populations, it is desirable to schedule a preliminary survey to obtain qualitative information on the character of the local fauna.

In practice, it is usually found most convenient and efficient to carry out surveys for one main species only or for a group of ecologically associated species rather than attempting to survey the entire fish fauna in an area.

The selection of species (or main objectives) will also depend on the fishing gear and other facilities available, including a tested survey methodology.

It is, nevertheless, possible to investigate a variety of benthic invertebrates, demersal fishes, and pelagic shelf forms during a single cruise and such multi-species surveys may in some cases be the most economic way of investigating these resources. Such cruises, however, set high demands on scientific and technical skill, and the distribution of effort required to investigate the various fauna elements may result in less than optimal sampling for any single species group. This can only be overcome by increasing the effort, i.e., by extending the survey time or the capacity and/or number of vessels used.

Regardless of physical facilities and personnel available, however, the concept of "total assessment" is not realistic with existing survey techniques. The establishment of priorities among species, then, is relegated to a subjective decision. Such factors as the importance of a particular species or species group to a local industry, to a nation or to the world community; the availability of fleets to take advantage of the defined resources; and the adequacy of the survey systems available, should be considered. In the final analysis, anticipated benefits, feasibility and relevance as they relate to the assigned mission will be determining factors.

3.3 Selecting the study area

The field investigators often do not have to make decisions about the area in which to conduct a survey. This is frequently laid down by the operational limitations given. There are times, however, when options are given in selecting the survey area. In such instances the investigator must consider the known distribution or behaviour patterns of the species or species groups to be studied, its (or their) distribution pattern relative to oceanographic and/or substrate features. Often the information will be fragmentary but adequate

to localize surveys in the most promising zones, i.e., demersal fish studies will be restricted "a priori" to the continental shelf and upper slope regions, certain tunas or other pelagic fishes are restricted to known thermal ranges, etc.

For demersal studies, the survey area may be further limited if data are available concerning the distribution of a species related to substrate or the bathymetric range of the exploitable sizes of the population. If the total demersal fish complex is the objective of the survey, then it is important to recognize that existing demersal fisheries frequently operate to depths of at least 1 000 m. Hence, the selected survey area may well include the greater part of the continental shelf and slope down to this depth. Modification of the study area may take place as a result of feedback from early survey activities. Similar consideration must be given to shellfish surveys. (See next section on factors governing sampling activity).

For pelagic fish studies, the investigator may have less tangible reference points; and, hence, must rely on antecedent knowledge of distribution patterns of species or species groups related to hydrographic factors (temperatures, currents, upwelling zones, areas of high basic productivity, convergences, etc.). A number of oceanographic atlases are now available which incorporate both physical and biological information of this character.

In addition to those factors that relate to the general ecology of the species being sought, the investigator should consider the logistic problems of the research vessel as well as those of the fishing fleet that might take advantage of positive results achieved. Quite often, however, in some areas there is no suitable fleet available to take advantage of a newly discovered fishable stock. The type, range, etc., of the future fleet required to exploit the resources discovered will have to be decided on the results of the exploratory work done, but the primary task of the survey is to map the resources wherever they might be within the overall limits of the survey area. However, if there is no clear choice provided by the available information on the distribution patterns of the species to be studied, and a local fishing capacity exists, then it is better to initiate the investigation in areas which are adjacent to port facilities and for which logistic aspects are such that they are likely to enhance fisheries development. Systematic expansion over alternate areas can be similarly selected.

3.4 Selecting vessel and gear

The choice of a vessel for exploratory fishing is important since it will have a direct influence on survey range and duration, the types of sampling gear that can be employed etc. However, in most cases, this selection is predetermined by the vessels already available or by the type of vessels to be chartered. Only in some instances have vessels been specifically designed for selected projects. In considering selection of a platform to conduct survey activities, one must, of course, consider the operational logistics in the area of operation, type of gear to be used from the vessel, and the needs of scientists as related to laboratory space, etc. If advanced acoustic equipment is to be employed, space required for equipment and operators must be included.

For many surveys, a trawler will be the best choice, because of its greater versatility compared to other types of vessels. With suitable deck arrangements, a trawler, particularly of the stern trawler type, is able to effectively operate and handle all types of bottom trawls, including shrimp trawls and high opening trawls for demersal species, midwater trawls for small pelagic species, as well as dredges and bottom samplers.

Once the area of investigation and survey objectives have been determined, plans must be laid for the sampling activity. The type of gear selected depends on the specific objective and the purpose for which the sampling gear will be employed. For example, if the sampling devices are to be used to develop indices of abundance, the selection of the gear may be different from that required for merely identifying targets detected during acoustic surveys.

The selection of sampling devices is always difficult and will depend on the objectives of the investigation and on the anticipated user of the information. From a scientific standpoint, one might want to use the most up-to-date trawl or other sampling devices, or a scaled-down version of some particular commercial gear. One should, however, be aware of the fact that if the equipment is too atypical of that normally employed by fishermen, both the scientist and the fisherman may have difficulty interpreting results because they may not reveal the commercial potential of the stock (Alverson and Pereyra, 1969). That is, they may provide information on the relative abundance, but they may not readily be interpreted in terms of harvest rates that might be sustained by commercial gears. Hence, in most instances, it is advisable to use gears of a size normally employed by commercial fishermen and which are in relatively standard use in many areas of the world (trawls, seines, longlines, dredges, etc.). On the other hand, there are times when new sampling schemes must be considered as existing commercial methods may not be applicable. In such instances, exploitation of the resource located may be contingent on the evolution of new fishing gear or strategy.

Once the investigator has selected and tested his gear and is reasonably satisfied with it as a sampling device, it is important that gear and procedures be standardized.

It should, in this connexion, be emphasized that resource assessment surveys do not constitute a programme in gear design, nor can one continue to experiment "ad infinitum" in an attempt to refine the gear to optimize catch rates. Such surveys have as their primary objective the determination of distribution and relative abundance patterns as well as first approximations of exploitable stock sizes. In this purpose, the sampling device does not necessarily have to be the most efficient fishing system and/or the fishing strategy perfected. In most instances, these problems will be considered during the subsequent stages of development of the fishery.

Regardless of what type of sampling gear is chosen, it is important that the investigator be familiar with its structural and fishing characteristics. For example, if a trawl is chosen, what are its dimensions, mesh sizes and tapers, what bridle system is employed, and what size of doors are to be used with the trawl? In this latter regard, the spreading device, doors, or floats, must be large enough to achieve an adequate spread and vertical opening of the net. It is also important to know the attitude of the gear during fishing; e.g., under normal towing speeds, what vertical and horizontal openings are actually achieved.

For purse seines, similar information is required concerning its length and depth, mesh size, hanging ratios, etc. The sinking rate, time required to complete pursing, and potential sampling volume are all important factors.

If the gear or vessel to be used for the survey are not of a type in commercial use, comparisons with commercial vessels should be conducted whenever possible. Selection of a relatively standard fishing gear is generally advisable since it allows some immediate interpretation of the economic aspects of resources.

3.5 Distribution of sampling activities

It is not necessary nor often desirable to choose the positions of sampling stations by a simple random selection of latitudes and longitudes from the entire survey area. More precise estimates can usually be made by using the well-known technique of stratified random sampling. Under this system the survey area is divided into a number of homogeneous sub-areas or strata which are treated independently. When the strata have been determined, the positions of stations within them are drawn at random.

The question arises as to what is the best characteristic for constructing the subareas or strata. For estimating a single item such as the abundance of a particular species the best characteristic is the relative distribution of the species itself. The next best is the relative distribution of some other characteristic highly correlated with the species distribution. In practice, however, we seldom seek a single estimate, nor do we know the relative abundance of a species before the survey. Sometimes we do not even know the distributions of depth, bottom types or oceanographic features. In these cases the stratum boundaries can be determined after a preliminary survey to determine the distribution (over the entire survey area) of the characters used for stratification. Of course, among the characters one can use is that of a measure of relative fish abundance. Other statistical techniques such as stratification after sampling or regression estimates are also available. The search phase is therefore an integral part of the total sampling effort and it may rely on acoustic devices, direct or indirect optical observations, test trawling with net, dummy chain, etc., (Hitz, et al., 1961), and on observations of environmental factors. Especially during pelagic fish surveys there will always be a search phase to determine relative abundance. The fishing is done here to identify detected target and/or to establish finer measurements of abundance. This in general also applies to demersal fish and shellfish surveys, except that flatfishes and, in most cases, shellfish, cannot be quantitatively detected with the present acoustic instrumentation. However, even when surveying for such species, a search for suitable depth and bottom conditions may at times be required in order to make the most efficient and economic allocation of fishing time. It should, however, always be borne in mind that the search phase of either pelagic or demersal study is an aid to allocating sampling effort by estimating the distribution of the characteristics used for stratification. The total number of samples are allocated among the strata either proportionately to the size of the strata or based on the expected variation of the character being estimated. In the latter case, more samples can be allocated to the strata for which more precise estimates are needed.

In a historical sense, most pelagic fish investigations have been designed to investigate concentrations of schooling fishes or species that tend to form large aggregates. For this reason, the concept of a predetermined sampling schedule is not practical as the probability of encountering a concentration precisely at a sampling station which has been prescheduled is extremely small. For this reason, investigations designed to study pelagic schooling fish must incorporate a search phase. Sampling gears can then be used to identify targets and to make estimates of their abundance. The search pattern itself is, however, often planned prior to the survey (Figure 1).

If little is known concerning the description of the species being investigated relating to environmental features, then the search pattern may merely constitute a number of evenly-spaced track lines running normally to (offshore, from) the general coast lines. In instances where previous information provides a clue as to the environmental features which tend to concentrate the species, the search pattern may be more non-random in a sense but respond more effectively to observed changes in the environment (Figure 2).

If the pelagic species being studied do not form schools or aggregates, then a predetermined sampling schedule will be desirable. From a logistic standpoint, the establishment of such a grid will depend on the size of the area to be studied, time available to the investigator, ship speed, time to set and use the sampling gear at each station, etc. If the hydrographic features throughout the area studied appear to be similar in character (homogeneous) the stations may be established at fixed intervals. If current boundaries, upwelling zones, or thermal boundaries appear to exist, then the investigator should increase the number of stations in such areas so as to more effectively measure changes in abundance that relate to these changing environmental features.

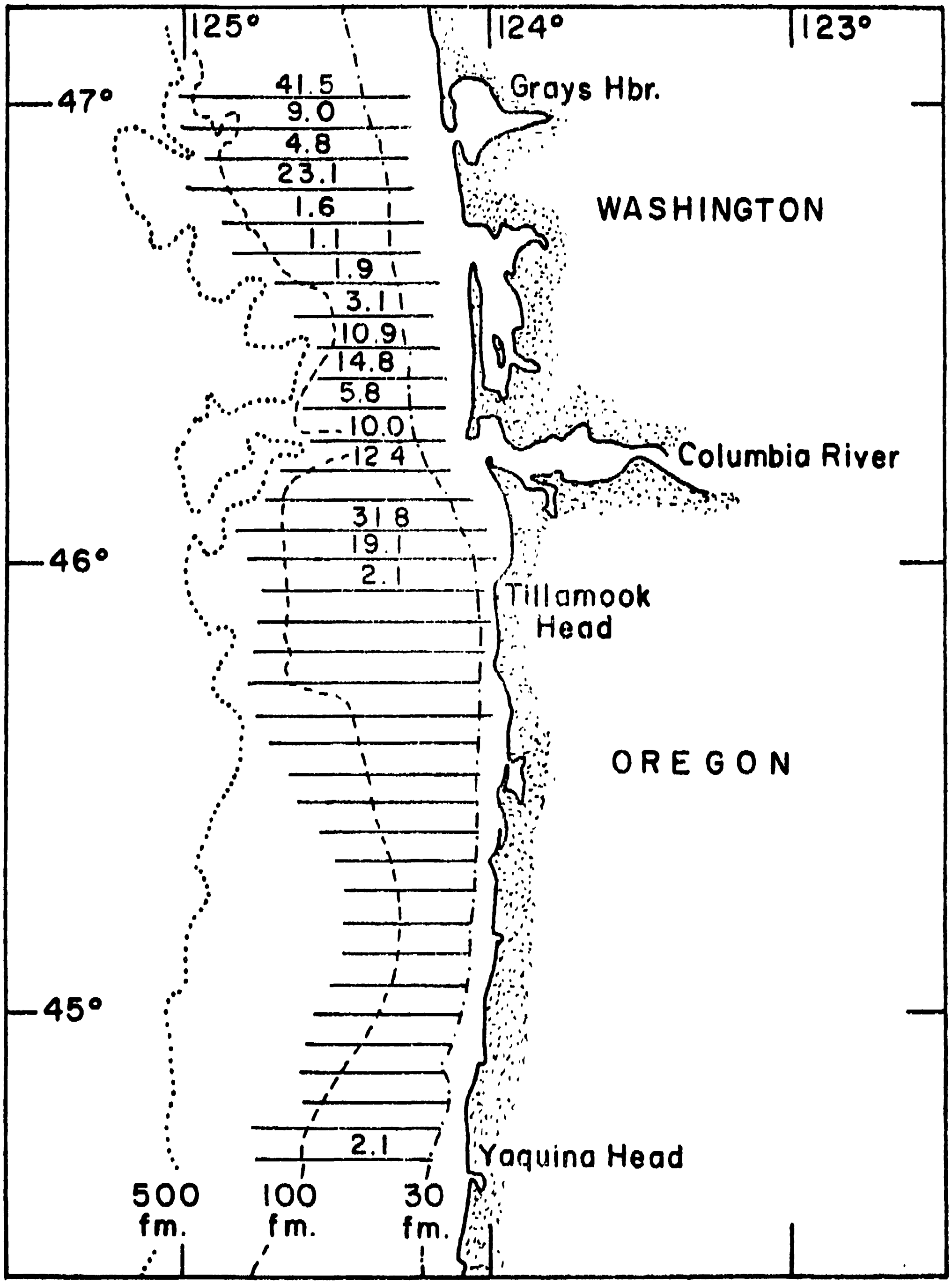

Figure 1. Positions of acoustical transects run by Soviet and U.S. scientists off the coasts of Oregon and Washington during calendar year 1969. Values shown are relative abundance of Pacific hake

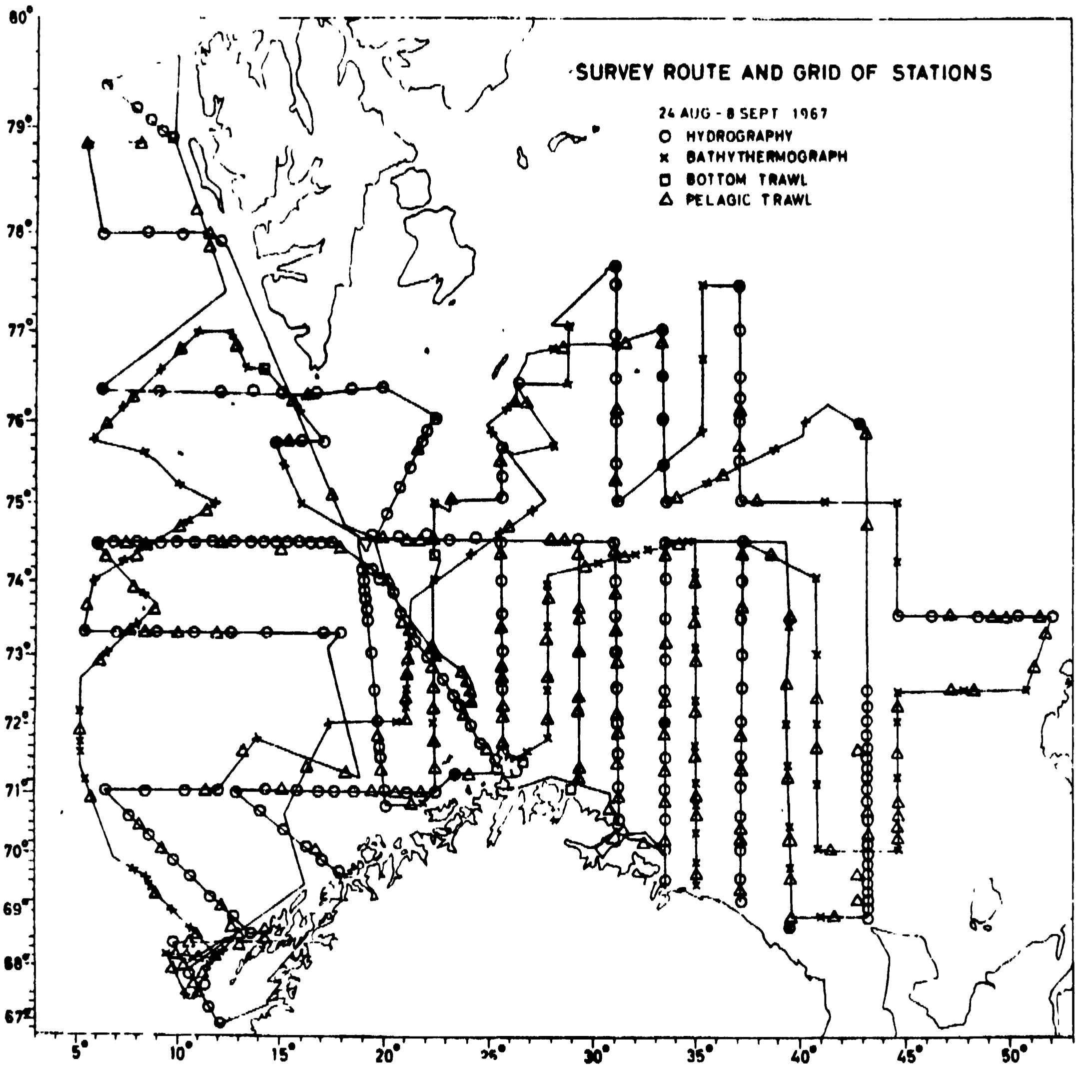

Figure 2. Survey route and grid of stations (from Preliminary Report of the joint international 0-group fish survey in the Barents Sea and adjacent waters August/September 1966, ICES, CM, 1966)

The distribution of demersal fish and shellfish is to a large degree contingent on depth and bottom conditions. A survey for these species therefore requires detailed observations on the bathymetry and substrata features of the continental shelf and slope. Where this information is missing, a pre-survey should be made to chart the depth conditions and to find suitable grounds for using bottom gear (Figure 3). In the case of roundfish and species which can be adequately detected by acoustic methods, this search phase should include a general search for major fish concentrations as well as observations on oceanographic features of the area. The composite information obtained can be used to develop the final survey pattern.

If the bottom characteristics in the area to be surveyed are free of obstructions, then a predetermined station pattern may be appropriate (Figure 4). In such instances, fishing stations will be concentrated in areas of major fish aggregations, but may otherwise be placed at fixed intervals or may be gauged according to changing depth. That is, a number of station lines may be established which are not normal to the coast line but the station's or any one track line may be contingent on the changing characteristics of the slope.

In those instances where the bottom features are such that they may preclude trawling, station patterns may be predetermined on the basis of placing one station within a fixed sub-area or grid. If this type of sampling schedule is planned, then the investigator merely locates a suitable area within each sub-area and conducts one or more sets of fishing effort in each grid. As previously noted, it may be desirable to increase the amount of sampling in those zones where the depth is dropping off sharply.

As the survey proceeds, one may wish to subsequently tailor the area of investigation to specific substrate characteristics. For example, shrimp surveys conducted in the northeast Pacific were generally more productive when c rried out in areas where certain mud types prevailed. These sediments were normally found in depths from 30 to 80 fathoms. Hence, the simple schedules for surveys were ultimately designed to concentrate effort within the depth zones and areas having the desired sediment features.

The time of the year during which the field survey is conducted can greatly influence the character of the results. Both pelagic and demersal fishes (throughout many areas of the world) are known to undertake geographic and/or bathymetric migrations. These movements result in sharp changes in abundance of a particular species of fish or groups of fishes found in a specified area. Hence, when investigations are restricted to one season of the year, many species that seasonally inhabit the area may be entirely missed and not reported as a latent resource. Further, from the standpoint of commercial utilization, seasonal changes in availability that result from aggregations for feeding or breeding purposes are extremely important; i.e., stocks that are largely dispersed during one season of the year may subsequently aggregate and hence become available to profitable fishing. The investigator therefore should consider seasonal coverage in areas investigated. The degree to which this can be accomplished will, of course, relate to the time and physical facilities available to the investigator. Seasonal surveys are, perhaps, most important in those areas where strong seasonal oceanographic changes occur; e.g., variations in current patterns, upwellings, temperature ranges, etc. Regardless, quarterly observations are generally adequate to portray seasonal changes in abundance and/or availability.

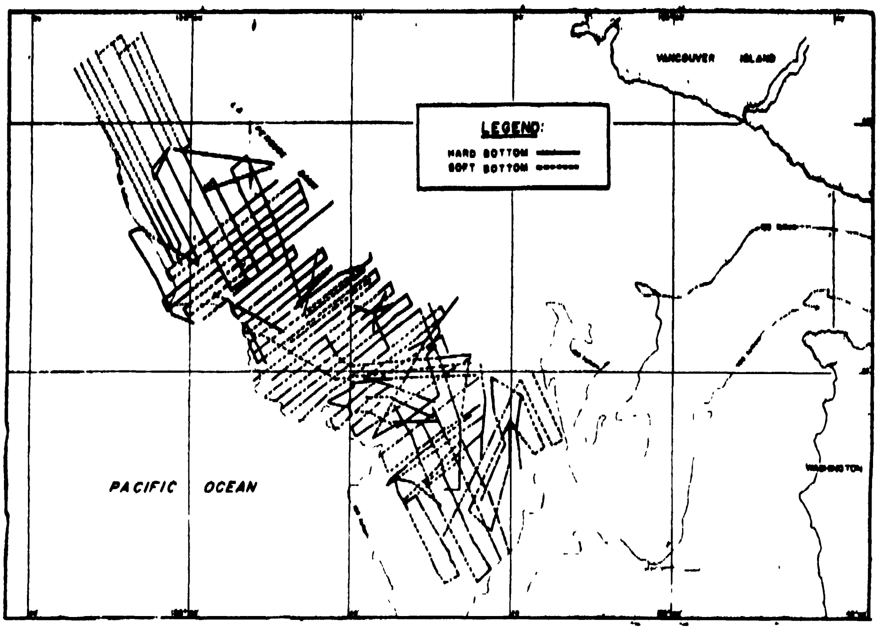

Figure 3. Track line and interpretative results from acoustical survey of bottom area off Vancouver Island, British Columbia

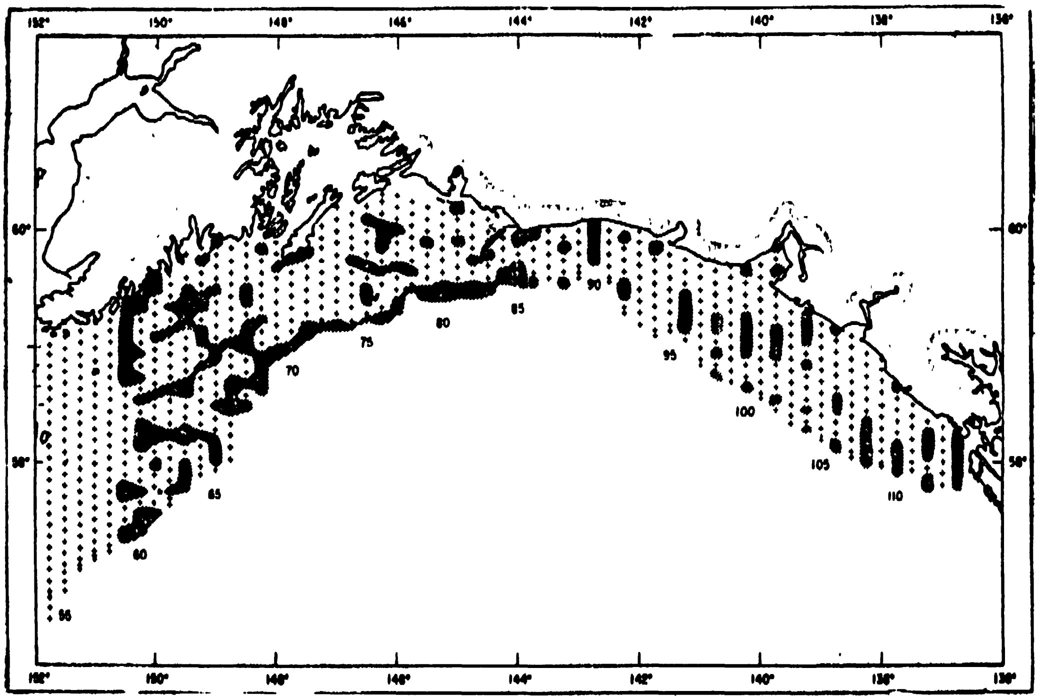

Figure 4. Pattern of stations sampled between the eastern end of Kodiak Island and Cape Spencer, Alaska, during the 1962-1963 survey. Non-trawlable areas are marked with diagonal shading. Lines of stations shown by plus (+) signs are numbered from left to right with every fifth line identified (IPHC, 1964)

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4. ACOUSTIC SURVEYS

Acoustic instruments are indispensible in most fisheries surveys. They are used for locating schools or individual fish and for assessing their distribution and abundance, as well as for surveying the depth and the nature of the sea bottom.

Echo sounders may be used to estimate the relative abundance and, in some cases, the absolute abundance of pelagic and some demersal fish. Sonar is used to locate and estimate the relative abundance of pelagic fish, but is not yet used for absolute estimates of abundance. The abundance of most pelagic fishes and round fishes can be estimated acoustically, in a relative or absolute manner; but flatfishes and other animals living very close to, or in the bottom cannot, with present techniques, be quantitatively detected.

The information from an echo sounder can be presented in two ways. The original method is to record the true depth of the sea, in a quasi-continuous manner, on a permanent or semi-permanent paper record. The records are quasi-continuous because the depth of the sea-bed or the range of a fish is measured by a pulse of sound lasting about 1 ms (0.1-5 ms) and which is repeated frequently (about once a second). Signals from fishes or from fish schools are recorded at intermediate ranges (usually the true depths of fishes or of fish schools are over-estimated by a few percent). The second method is to record the voltages from fishes or from schools on a C.R.T. (cathode ray tube) or on a voltage integrator; many forms of fish counters are based on the analysis and summation of voltages. The paper record, with its limited dynamic range, shows the presence of a voltage in any transmission but not its quantity; its great advantage is its "memory" by which the distribution of fishes and fish schools in time is displayed. The C.R.T. displays voltages from fishes and fish schools accurately, but in a transitory manner. Echo integrators and fish counters can be used to record true voltages by depth ranges in time series.

No method exists as yet for identifying fish targets acoustically, although the different species in an area usually present signals with different characteristics. Reconnaisance surveys of the fishing grounds can therefore be made using acoustic instruments. Similarly, because of the relationship that exists between size of target and echo strength, the echo records also tell whether the fish recorded are large or small. With suitable equipment, it is even possible to estimate the actual size distribution.

In the search for fishing grounds (bottom types, etc.), fishermen and fisheries biologists (Hitz, 1961) use echo sounders, but this is a field which has been relatively weakly documented and is probably rather unexploited.

4.1 Selection of fishing grounds

There is an obvious way in which echo sounders are used for selecting grounds, in the presence of fish traces on or near the bottom, or by eliminating ground which is obviously much too rough for use of the gear.

Fishermen have used wide-beam echo sounders for this purpose for a very long time. If the bottom is hard, signals are returned from much of the wide beam; and the record of the bottom echo is of considerable vertical extent because it continues in time after the first signal from the sea-bed has been received. Conversely, if the bottom is soft, the record of the bottom echo is of little vertical extent. Hence, the hardness or softness of the bottom can be estimated directly by inspection of the echo record. With a calibrated echo sounder equipped with a C.R.T. display, the signal from the sea-bed itself can be measured. In this way, for example, the muddy areas of prawn fishing grounds have been accurately determined, and the method may prove to be useful for locating suitable trawling grounds in general (Rollefsen, 1938; Vestnes, personal communication); it is interesting to recall that Rollefsen (1938) made similar surveys with less developed equipment. It is, however, difficult with a wide beam echo sounder to detect areas of smooth bottom which are obstructed

by rocks or boulders so as to make the ground untrawlable. For this purpose the method developed by Chesterman, et al. (1958) to detect wrecks, mines, etc., in shallow waters, may be found useful. This method, called "side scanning", uses a fan beam, narrow in the horizontal dimension and very wide in the vertical, and the display consists of a plan chart bounded by the ship's track and the maximum range. The same method can be used for charting the positions of pelagic fish shoals, in plan.

The charts from the side scan sonar show complex patterns in shallow water that may reflect particles of different sizes or which may be bottom conformations; it is sometimes difficult to distinguish the two. Stubbs and Lawrie (1962) used the method successfully to chart a herring spawning ground in detail on the Ballantrae Banks in the Clyde estuary. It is possible that some of the rough grounds avoided by fishermen in deep water could be charted readily with powerful equipment, such as the one recently introduced by the National Institute of Oceanography in Great Britain for geological purposes, a deep-water-side-scan sonar emitting 60 kw and receiving on 120 channels. Another possibility is sector scanning equipment used in the vertical mode (i.e., with the narrow beam scanning in the vertical plane) to examine the bottom conformations and the presence of fish with respect to them on bearings from the ship's head. However, neither the side scan sonar nor the sector scanner in the vertical mode have yet been used for such purposes.

4.2 Evaluation of relative abundance

The early use of echo sounders (summarized in Hodgson and Fridriksson, 1955) was essentially qualitative, and a trace of fish on the paper record indicated the presence of fish. No index of numbers was considered, and even the apparent absence of fish was mistrusted - quite rightly. The first fishermen to employ the machines were the herring fishermen in the North Sea and those off Vancouver, B.C., Canada, who shot their driftnets in areas where fish traces were found. Fisheries biologists started to devise methods of echo survey by using echo sounders which showed patches indicating the presence of fish. (Sund, 1939).

Runnstrøm (1941) and Sund (1943) published echo surveys of herring off the Norwegian coast as positions of fish trace along the course track. Runnstrøm's surveys showed herring on the Utsira spawning grounds during February 1937, and he considered the lack of trace to be absence of fish. In subsequent years a number of surveys were made in this way (see Hodgson and Fridriksson, 1955).

Cushing (1952) extended this method and obtained an estimate of the horizontal extent of the trace by measuring, with a binocular microscope or a ruler, the width of the mark on the paper record. Thus, each transmission was examined for the presence or absence of echoes. In general, such surveys were made in the North Sea and English Channel where the depth of water was not great and signals were not lost in the noise in deeper water. Because the signal-to-noise ratio used on the early echo sounders tended to be low, a signal from fish was recognized only when repeated at about the same depth in successive transmissions. In other words, a form of trace-to-trace correlation was adopted; and while the method cannot be employed to determine the absolute abundance of fish directly, it can and has been used to give estimates of relative abundance. It was applied in a number of investigations, especially of pelagic fish (e.g., Cushing, 1952).

Figure 5 shows an echo survey of pelagic fish in the English Channel made in the summer of 1949. During the cruise, samples of pilchard eggs were being taken. There is an association between the distribution of eggs and that of the echo traces which provides a general identification of the majority of traces in the whole area. The egg survey yielded estimates of the numbers of pilchards and the echo survey, numbers of schools; hence, the number of fish per school was obtained by dividing one into the other.

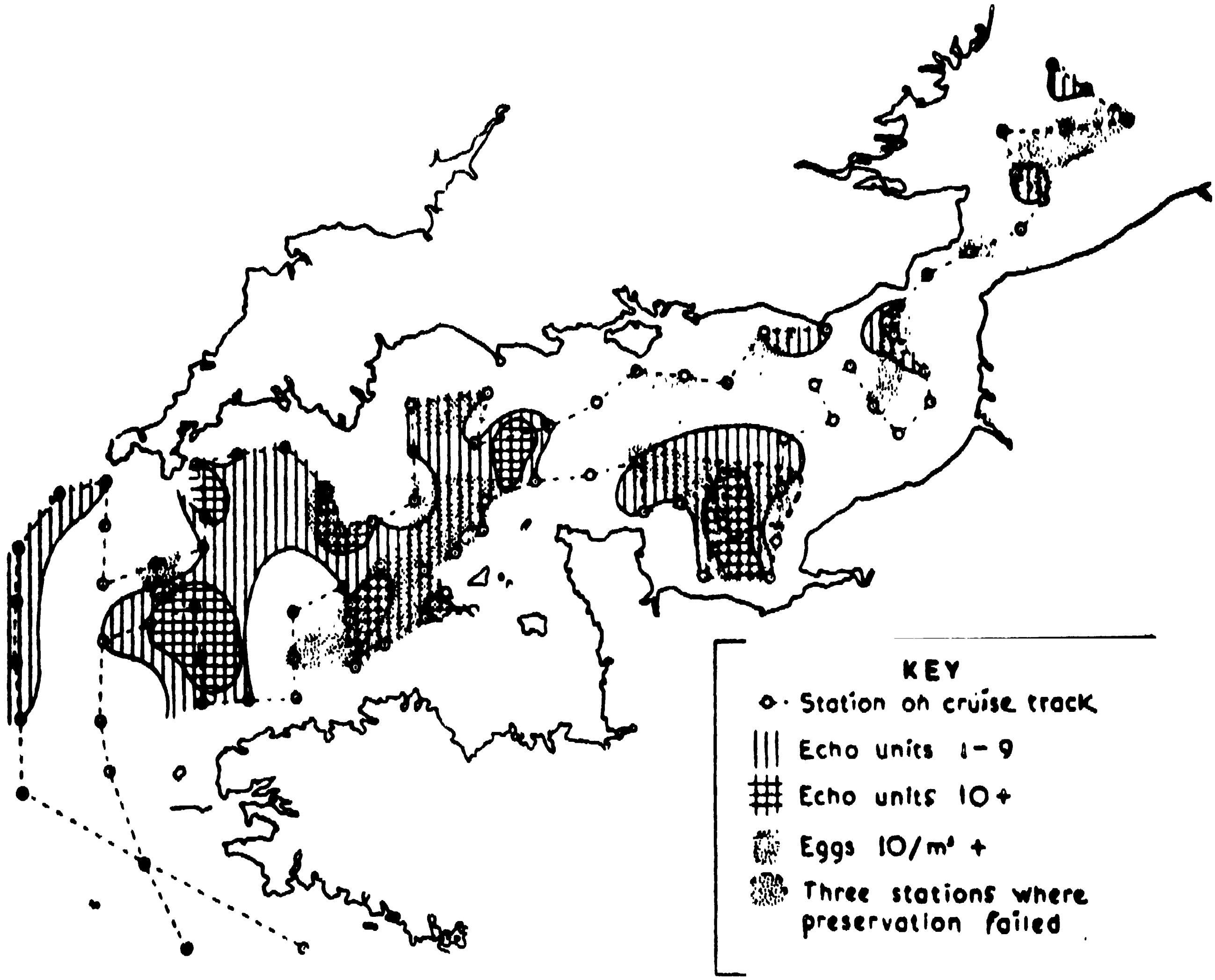


Figure 5. Cruise XI, Sir Lancelot, 1949. Comparison of echo-patch and the distribution of Stage I pilchard eggs

Such methods of estimating relative abundance were described in the early stages of development, but, of course, are still used with considerable effect throughout the world. A good example is the work carried out from the Exploratory Base in Pascagoula, Mississippi, U.S.A; the records are classified by percentage of the paper filled with echo trace. Such data are presented by area, depth, and season; and a considerable quantity of information on the presence and absence of trace is made available. A further classification by percentage of fish schools and by percentage of scattered fish in the same categories reveals changes in behaviour pattern throughout time and space within the area of study.

Considerable work has been carried out on estimates of relative abundance using sonar, essentially by recording the number of schools detected in the area examined. Because sonar had been used in the second world war to detect submarines, attempts were made immediately afterwards to use it to find fish. Thus, Lea (1946) and Gerhardsen (1946) proved that sonar was readily applicable for locating Atlanta-Scandian herring schools, and Renou and Tchernia (1947) surveyed the winter herring fisheries in the eastern English Channel with sonar.

Subsequent work showed that the patches of fish which they located were in fact the herring spawning on the Downs grounds (Cushing, 1966). But the most dramatic work with sonar was that started by Devold (1950, 1952) on the migration of Atlanta-Scandian herring toward the coast of Norway. In the early fifties, he showed that Atlanta-Scandian herring living in summer on the polar front between Iceland and Jan Mayen, migrated in the east Icelandic current south-eastward from Iceland to north of the Shetland Isles in autumn; and then at a depth of about 75 fm they crossed the warm Atlantic current rather quickly before striking the coast of Norway (Devold, 1968). By means of this remarkable and persistent work, Devold has described the whole migratory pattern of the Norwegian herring right across the Norwegian Sea at all seasons with the use of sonar alone.

4.3 The estimation of absolute abundance

So far, the estimation of relative abundance with an echo sounder has been considered. However, with more detailed analysis of paper records, of received voltages, and of standard measurements of signals from single fishes (or of their target strength), it is possible to estimate the absolute abundance of fish stocks. It must be recalled that the targets sampled acoustically should be identified by capture. The methods are treated more fully in the FAO manual on the use of acoustic instruments in fish detection and fish abundance estimation. The section which follows summarizes the methods used from the viewpoint of resource surveys.

4.3.1 Signals from single fish

The first stage in the development of method was the recognition that "fingernail" traces represent single fish on the paper record. Such a trace usually looks like the tip of a fingernail on the paper record and it endures for a number of transmissions. For each transmission, its duration in time is minimal; if the duration of the received pulse is greater than one or two pulse lengths, the trace is generated by a small school. Saetersdal and Midttun (1957) initiated a number of surveys of the Arcto-Norwegian stock of cod off northern Norway based on the distributions of the echoes from large single fish in mid-water, which they reasonably assumed to be cod. At about the same time, Richardson, et al., (1959) were developing a method for estimating the abundance of cod on the bottom of the Svalbard Shelf. Here, signals were counted and their amplitudes measured in a scan of a fathom or two off the bottom on a cathode ray tube A-scan display and the amplitudes of received signals were corrected for different depths. Frequent trawl hauls ensured that the identification of the echoes as cod was maintained, and with the exception of a small quantity of haddock in shallow water and a few redfish in deep water, the surveys charted the distribution of cod.

If fish can be recorded as individuals, it follows that it may be possible to obtain estimates of absolute abundance from echo surveys. The estimates of absolute abundance made in this way will, of course, only apply to the depth range within which the individual fish can be detected by the echo sounder in use. It is important, therefore, that the maximum depth to which the signal from a fish of given size can be detected should be known. This is a function of the target strength of the fish and the acoustic properties of the echo sounder, which are expressed in the sonar equation as follows:

$$EL = SL + TS - 2H,$$

Where EL is echo level observed in decibels (dB); SL is the source level of the transducer in dB//1μBar; TS is the target strength of the fish in dB; H is the one-way propagation loss in dB (i.e., losses due to range and attenuation).

From this equation the signal, or echo level, for any size of fish can be calculated on the acoustic axis at any range to a maximum defined by the signal-to-noise ratio. Then, if no signal was received in a given volume of water at any range less than the maximum, then there were no fish of the prescribed size in it. It follows that knowledge of target strength of fish is needed.

A good series of measurements of target strength was made by Midttun and Hoff (1962), who showed that target strength increases roughly as the volume of the fish. They worked at fairly long ranges on freshly killed fish which had been kept at the depth of observation when alive; thus, the swimbladder was intact and at the right volume when the measurements were made. The results of Midttun and Hoff together with the best measurements from Cushing, et al., (1963) are shown in Figure 6 as a plot of target strength in decibels on fish length in logarithms and they will be used in further discussions on the dependence of target strength on size of fish.

As target strength increases at slightly less than the cube of the length, size discrimination of individual fishes should be possible. It is a fortunate accident that organisms other than fish do not, in general, yield signals of the same order of magnitude· squids do so and fish without swimbladders have smaller target strengths, but in general it is fish which are recorded by echo sounders. (Cushing, Lee, and Richardson, 1956, and Cushing and Richardson, 1957, consider the evidence for signals from other sources).

4.3.2 Statistical treatment of signals in angle

If all fish were found at the axis of the sound beams, differences in signal at any one range would be differences in size. The directivity coefficient (δ^2) decreases in angle Θ from the axis to the first minimum; the squared coefficient is used for signals from echoes (or the directivity distribution in transmission is multiplied by that in reception). The number of fish, however, increases with the square of the angle Θ because the beam spreads over an area at any one range. Figure 7 shows the two distributions and the product distribution; the latter peaks at a mean angle Θm with a directivity coefficient, δ_m. We consider that the signals are distributed about the mean angle.

The sampling volume of an echo sounder is described by the maximum range of the target (of a fish of given size) and the beam angle. At a less range, δ_m^2 can be calculated (see FAO Manual on the use of acoustic instruments in fish detection and fish abundance estimations, Parrish, 1969). Then,

$$EL_m = EL\delta_m^2$$

where EL is the echo level on the acoustic axis, at a given range, in dB; EL_m is the echo level at the mean angle in dB at a given range. Given the components of the sonar equation EL_m is calculable for all ranges to R_{max} for a given size of fish. Figure 8 shows the calculated relation of echo level on range for fish of different target strengths; the relationship was calculated for a Kelvin Hughes Humber gear with a source level of 128.9 dB//1μBar dB/with reference to 1μBar and a beam angle of 9° x 14° in echo to the first minima. An average beam angle of 11.8° was used.

In the sonar equation the one-way propagation loss accounts for the effects of range and attenuation in reducing the signal. A time-varied gain eliminates this effect; when noise is measured, a threshold setting in μV on such a gain is put at a conventional signal-to-noise ratio. The effect of this procedure is to record all signals from fish on the acoustic axis on the same scale and so differences in signal are then only differences in sizes of fish whatever the range from which they are received. However, fish are distributed in angle at any one depth, there are differences in signal due to angle as well as to size. Figure 9 shows the signals expected from different sizes of fish at different ranges with a Humber gear and time varied gain at the same threshold setting for all ranges.

NOTE: Decibel (dB) is a ratio of intensities in logarithmic units, e.g., $N = 10/\log_{10} I_1/I_2$ dB, where I_1 and I_2 are two intensities.

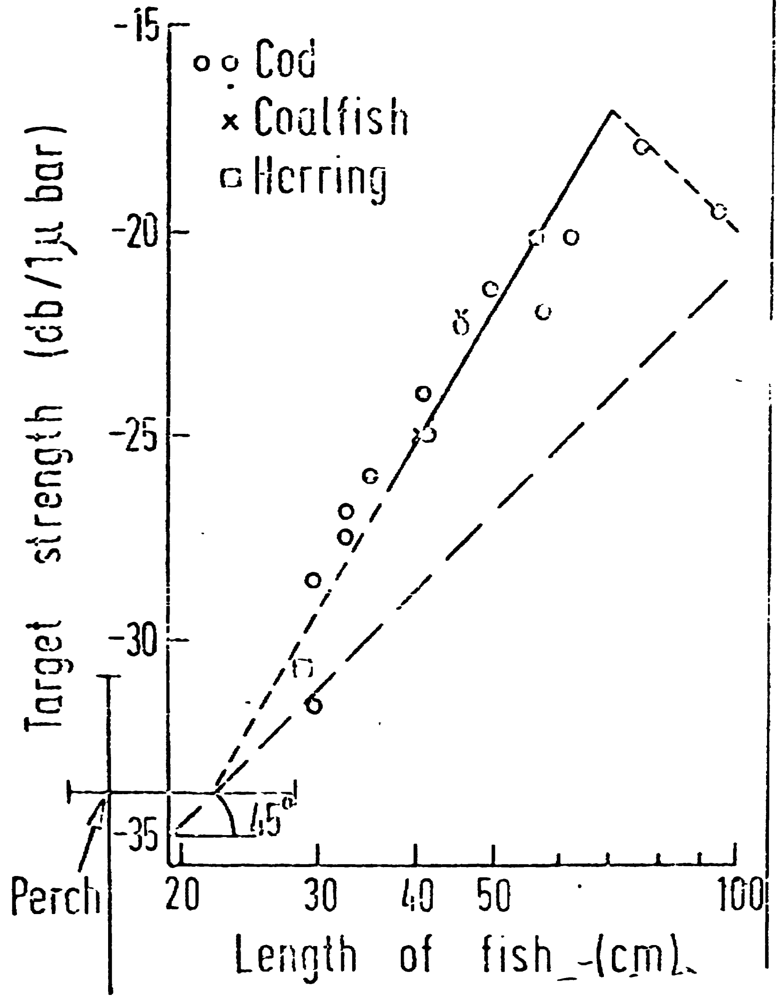


Figure 6. Target strength of fish in decibels vs. length of fish (logarithmic scale)

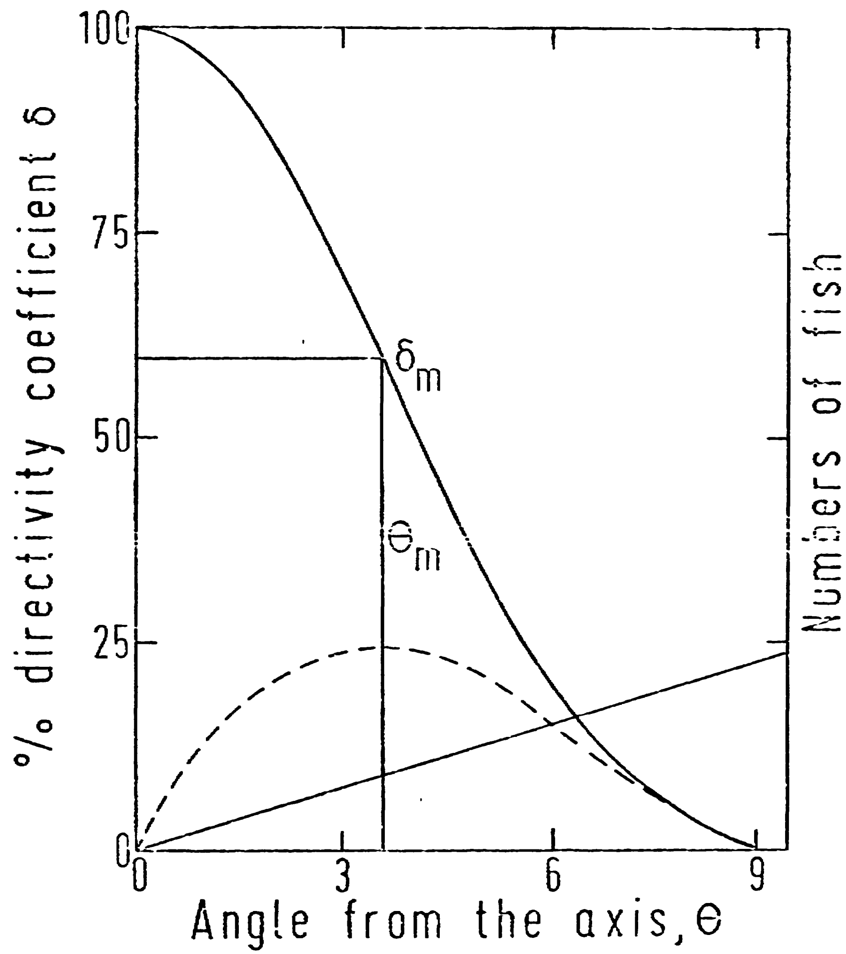


Figure 7. Relationship of percent directivity coefficient vs. angle from axis (theta) and number of fish

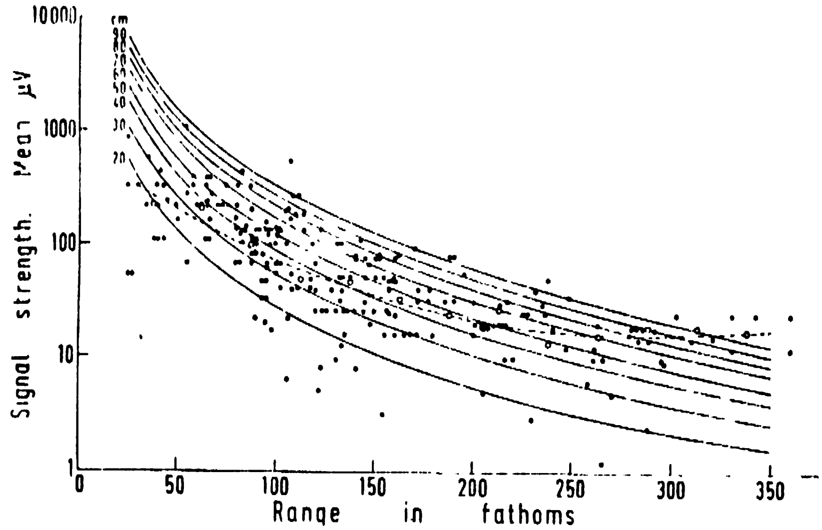


Figure 8. Theoretical curves of signal strength ($T.r^{-2}.\delta m$) on range for fishes from 20 to 90 cm long, from Cushing (1968)

4.3.3 Volume sampled by the echo sounder

It follows from the sonar equation that fish of different sizes are sampled to different maximum ranges, increasing with increasing size of fish. (For details, see Parrish, 1969.) For a square transducer, the range shell volume between R_1 and R_2 (in m) and out to θ_{min} in angle is defined as:

$$\frac{2}{3}(R_2^3 - R_1^3)\ (1 - \cos\theta_{min})$$

in m^3, and, for a rectangular transducer, by:

$$\frac{2}{3}(R_2^3 - R_1^3)\ (1 - \cos\sqrt{\theta\delta\theta\beta})$$

in m^3, where $\theta\delta$ and $\theta\beta$ are the angles subtended by the major ($R \sin \theta\delta_{min}$) and minor ($R \sin \theta\beta_{min}$) axes of an ellipse at a range R. The range shell volume is that in which a signal from a fish can be detected. It can be split into sections of angle θ. Each section is multiplied by the appropriate directivity coefficient and the sum of all sections so weighted is the effective column sampled; it takes into account the chance of detection varying with directivity.

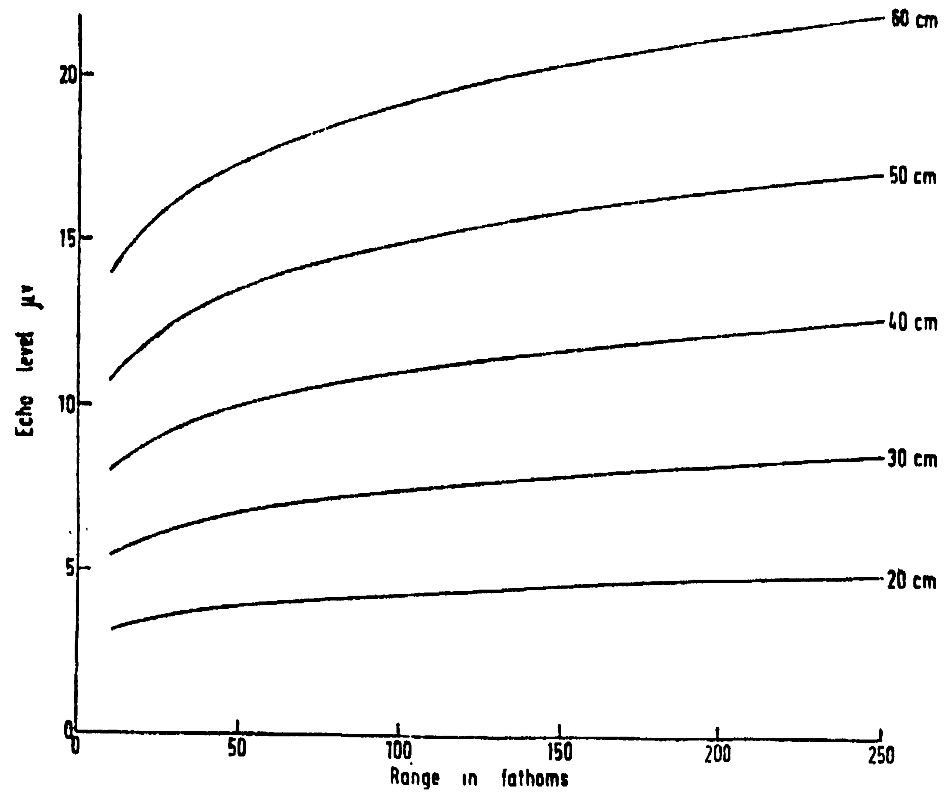
There are two ways in which fish can be counted:

(1) as a number of traces per unit volume over a large number of transmissions;

(2) as a number of signals per unit volume within one transmission.

The first - trace counting - is used when the fish are counted visually from a paper record, and the second - signal counting - is used with automatic counters.

The volumes used in the two methods differ. That in the signal counting method is the simple range shell volume corrected for the change of detecting signals at different angles. That in the trace counting method is more complex, being a projection of a single elliptical shell on to a vertical plane at right angles to the ship's course, which is extended along the ship's track for a given distance (see Cushing, 1968).



<u>Figure 9.</u> The calculated relationship of echo level on range for different sizes of fish using a time varied gain, at a given threshold setting

There are statistical differences between the two procedures. With signal counting, the distribution is essentially the product distribution shown in Figure 7. In principle, it is easy to handle and can be used to extract size distributions from all the information received. With trace counting, the distributions are difficult to handle.

The two counting procedures, trace counting and signal counting, are related to different sampling volumes and to different statistical formulations. The signal counting procedure is based on the simplest volume and simpler statistics, but it needs automatic processing (Dragesund and Olsen, 1965; Mitson and Wood, 1961). The trace counting procedure needs no automation, but the estimation of volume and of the distributions are rather more complex.

4.4 <u>Automatic data processing of echo counting information</u>

The first step in any automatic data processing is the separation of signals from single fish and those from schools of fish; the Lowestoft single fish/school discriminator makes such a separation on the basis of the number of cycles received. The second step is to establish the mean size of fish sampled within a short range gate from the mean signal received from single fishes for a fairly short time period; such averaging procedure may be carried out with a storage oscilloscope, sampling voltmeter, or a pulse height analyzer. If a time varied gain is used, as described above, differences in size are greater than differences due to range for quite large steps in range (see Figure 10) and this is the real virtue of using a time varied gain. The third step, given the mean size of the fish within a short range gate for a short period of time, is to establish the expected distribution of

signals from fish of that size, which would really be one of directivity in voltage for fish of that size. Thus, a distribution of deviations from such a distribution would effectively be a voltage, hence length, distribution of all the fish sampled. Hence, the signals from the averaging procedure must be delayed long enough for the third step to be completed.

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5. DATA COLLECTION AND RECORDING

The planning of the fisheries survey must provide for orderly and efficient performance of all the tasks that are involved, from the selection of the vessel and gear and its outfitting, to the submission of the final report. In the entire operation, proper recording and processing of the data are as important to the success as is the efficient operation of the vessel and its gear.

5.1 Data selection

The question of what type of information should be collected during exploratory fishing cruises is one of continuing difficulty for the investigator. All too often the tendency is to programme the data collection far beyond the capability of satisfactory documentation by a limited staff. In the ideal situation, it would be desirable to have an extensive series of hydrographic observations as well as information on the numbers, size, weight, age, etc., of the fish being sampled. Some decision, however, based on primary work objectives, must be made between what is desired in terms of observations made and records maintained and what is practical due to staff and vessel limitations.

The minimum data to be documented during exploratory fishing include:

(1) precise identification of the location and time of sampling;

(2) as complete identification of faunal elements as possible; and

(3) indices of abundance.

The latter will depend on accurate estimates of the weights and numbers of various animals captured, and of the fishing effort required to capture them.

5.2 Data records

Substantial amounts of data will almost always be involved in survey records. The resulting requirement for numerous summaries will often call for some level of automatic data processing (ADP) at least to the level of punch-cards which can be sorted for tabulation in various ways. If there is any expectation that the results of a given survey may need to be considered in detail in association with those of other surveys, such as is the case of studying seasonal changes in stock availability, ADP becomes especially important.

Use of punch card storage and subsequently ADP systems can be facilitated through properly designed data collection forms. The design of such forms requires the availability of expertise in this special work, and investigators who plan to take advantage of ADP should consult such experts when preparing data sheets. A number of such forms have already been designed and examples are described and discussed in this section. They are generally adaptable to other situations, but data processing experts should still be associated with that aspect of survey planning which deals with the data to be collected since the arrangement of data forms and recordings will exert a major influence on the operations on the survey vessel.

Observations to be made on the survey generally fall into several classes. These classes should be considered separately for purposes of recording and subsequent analysis.

The classes of records may be identified as follows:

(1) the survey identification and description;

(2) the individual station identification and description;

(3) the catch information;

(4) special biological information.

Required observations in each of the categories should be obvious from the data record forms. It is poor practice to use forms which provide for the entry of more information than is really wanted. It is equally unwise to ask the observer to "write-in" much information which is not clearly specified on the forms or which may call for exercise of a large degree of subjectivity by the observer. The records form designer must remain fully aware of the often very difficult and exhausting circumstances under which the field observers must work and of the large amounts of data which may be required. When the complex set of catch forms is being designed, it is especially important to make the entire sequence of observations and recordings as routine as possible.

5.3 Survey identification and description

The data collected and filed as the result of a survey cruise must be clearly identified by a descriptive term or by a simple code for purposes of data checking and processing. This term will generally be devised in such a way as to specify the ship used or the survey sponsor and a cruise number. The code name should be assigned at the outset of the cruise plan. Since it will appear on each of the data sheets of the cruise, it should be kept short - both to avoid unnecessary work and to occupy as little data recording space as possible. This is especially important if ADP is to be used.

If only one or two vessels and kinds of sampling gear are to be used on the trip, it may be convenient to devise a form which can be used to develop appropriate descriptions.

Since certain vessel characteristics will influence its relative fishing power, care should be taken to ensure that the record includes a good vessel description appropriate for recording parameters for different types of vessels (e.g., at a minimum this must include LOA, engine horsepower, gross tonnage, vessel type, crew size, special electronic and deck equipment).

Similar information needs to be recorded for the fishing and other gear. Parameters needed for adequate description vary with the gear, and suggestions are made in Appendix II. Reference may be made to other standard descriptions, such as are given by Scharfe (1964) for midwater trawls.

5.4 Station identification and description

Station identification and description records contain the information that will be correlated with the catch and biological data during analyses or used to stratify the information by area, depth, temperature, etc., during data processing. Particular attention must be given to an appropriate measure of fishing effort, since the main purpose of the survey is to establish a measure of fishing success, or the catch per unit of effort. Commonly used indices are catch per unit time per (1) haul (tow), (2) purse seine shot, (3) fixed length of gillnet, (4) number of longline hooks, (5) number of pots, etc. Time not expended in actually fishing should be excluded; e.g., time lost through bad weather and time steaming to and from grounds and time during which the gear is being repaired. When a search pattern is used, the time spent locating aggregates must be incorporated in the abundance indices.

In general, the information to be recorded can be classified into identification, position, time and equipment plus the oceanographic, topographic, or meteorological observations.

A description and elaboration of each class of information follows, illustrated by reference to the upper portion of the Demersal and Pelagic Catch Form of the FAO Regional Fisheries Survey in West Africa (Figure 10). This form is used as both a data recording form and as a source document for keypunching the data in cards used for the ADP system.

5.4.1 Identification

The identification section of the form consists of the four items labelled: project, vessel, cruise number, and haul number. The name of the survey of its sponsor, as well as the vessel name, are coded items. A new cruise number is usually assigned each time the vessel leaves home port and is used to mark or identify all the data sheets of the survey cruise.

One of the key items included in this part of the record is the station number or haul number. Station numbers are the principal means of identification of the various parts of the survey data. The order of numbers should usually correspond to the time sequence of data collecting; that is, a different number should be assigned to each successive operation. Unfortunately, the terms "station" or "station number" are sometimes taken to denote a specific area, or a position where replicated sampling is conducted. As a rule during the data editing process, station numbers which reflect the sequence of events are more reliable and unambiguous for checking on the sorting, recombination and completeness of the recorded data. Consequently, a survey based on a grid system or which employs repeat sampling in a given location should assign station numbers in sequence in addition to using codes to identify the grid position or area of the survey operations.

It has been noted in Chapter 2 that acoustic detection and recording are an important adjunct to the information collected by fishing gears. Continuous recording may be made during the fishing operation as well as on runs between stations.

Continuous recording does not lend itself readily to assignment of regular station numbers. The important consideration is to graduate the continuous record at the time of recording into units of distance or time so that various sections of the record can be later identified. It is the various sections of the continuous recording which need to be associated with the catch information. For this purpose, a special echo-sounder log, such as shown in Figure 11, for the West African Regional Fisheries Survey should be employed. Separate lines of the log sheet should be used to record time and position of the start and finish of each section. Care should be taken to identify runs between stations separately from soundings taken during towing. For the latter recordings, cross-reference should be made to the appropriate fishing station identification code.

The information collected by the echo-sounder is peculiar to the instrument used. The types of records and their treatment are briefly discussed in Chapters 3 and 4 and at length in the FAO Fisheries Manual of Methods for Fish Stock Assessment, Part V: The Use of Acoustic Instruments in Fish Detection and Fish Abundance Estimation. (FAO Fish.tech.Pap., (83)).

5.4.2 Time and duration of fishing

The year, month, and day of operations, as well as the beginning hour and duration of fishing operations, must be recorded.

For example, a space for entering the "time of shooting" or beginning of the fishing operation is recorded on the sample sheet. It may be used during analysis to stratify the catch, effort, and catch rates by time of day for the purpose of analysing changes in vulnerability to the net caused by behavioural changes that may be related to daily cycles.

Demersal and Pelagic Catch Form

PROJECT	VESSEL	CRUISE NUMBER	HAUL NUMBER	DATE			QUADRANT	POSITION		MEAN BOTTOM DEPTH	MEAN FISHING DEPTH	TIME OF SHOOTING	DURATION / EFFORT	TRANSPARENCY	SALINITY	OXYGEN	TEMPERATURE	THERMOCLINE DEPTH	BOTTOM TYPE	WARP OUT	GEAR TYPE	PERFORMANCE	SONAR / NETZSONDE	SCHOOLS PER CATCH
				YEAR	MONTH	DAY		LAT.	LONG.															
1	2	4	6	8	10	12	13	17	21	24	27	30	32	34	37	40	43	45	46	49	51			55

ECHO INT.	Sc. Layer	S. Fish		SPECIES	WEIGHT	NUMBER	Card Type	REMARKS	SPECIES	WEIGHT	NUMBER	Card Type	REMARKS
58			62	67	73	78			63 67	73	78		

Figure 10. Demersal and pelagic catch form used by FAO Regional Fisheries Survey in West Africa

LOCALITY	LAT	LONG.	LEADER	SHEET NO.	DATE

SHIP				SONAR	ECHO SOUNDER																						OBSERVER		TIME
HOUR	LOG	COURSE	SPEED	NUMBER OF CONTACTS	SCHOOLS								SCATT. LAYER								SINGLE FISH						DEPTH BOTTOM METRES	SURFACE TEMP °C	NOTES
					NO	EXT	DEPTH		NO	EXT	DEPTH		TYPE	QTY	DEPTH		TYPE	QTY	DEPTH		QTY	DEPTH		SCOPE		TS. DB			
							FROM	TO			FROM	TO			FROM	TO			FROM	TO		FROM	TO	Y CM	DEF				
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NOTES:	TRANSDUCER	T.V.G. AND GAIN LOG.R dB
	RECORDER RANGE	BANDW. AND PULSEL.
	RECORDER AMPL. GAIN	OUTPUT POWER

Similarly, the amount of moonlight can affect the catch rates during nighttime fishing operations that depend on sighting schools. For this reason, most pelagic fishing surveys also record the time-related phase of the moon.

The measurement of fishing effort requires a record of the duration of the fishing operation. The definition of this operation will depend on the type of gear and the nature of the survey. For example, in trawling operations, the duration of fishing should be measured from the time shooting of the trawl is completed or the net reaches the bottom and begins fishing (if this is known) until the beginning of the net lifting operations.

In fishing operations which have a search phase, such as purse seining, the time devoted to searching must be recorded separately from fishing time as an index of the total effort. For example, the best index of abundance of pelagic fish schools may be the number of schools sighted visually or with acoustic gear per unit of time or unit area searched. However, the actual duration of the net setting and hauling operation, with an allowance for the fixed time of preparation, is related to the size of the individual schools. Thus, both searching time between net sets and the time of setting and hauling are required for complete effort information on seining operations. Similar considerations apply to demersal fish operations when sounders are used in scouting for fish.

In Appendix II, fishing time measures, appropriate to the various types of gear, are listed.

5.4.3 Position

The appropriate standardized reference to fishing position of the station is, of course, the latitude and longitude. However, in many instances position observations are made in terms of Loran or Decca bearings, depths, or distance and direction from a landmark. These should be entered on the appropriate log sheets and used to compute the latitude and longitude at a convenient time.

The case of repeated sampling of a position has been mentioned in the identification section. In many situations it may be possible to stratify the area into sampling zones when the cruise plan is drawn up. Where such strata (depth zones for instance) are set up, appropriate codes can be given to these locations and employed to identify and associate the records collected in a particular area.

5.4.4 Equipment

The equipment and gear used at each station is usually recorded in the station description section of the data form. This is essential if gear changes are made during the survey. Otherwise, the data on gear and equipment can be referenced for the whole survey in the survey identification forms and reports.

The type of fishing gear, Appendix II, and specialized instruments are generally coded items of data. The code should give reference to a complete description including accessories and attachments to the equipment, as discussed in the foregoing section on "Survey identification and description".

Closely associated with the equipment specifications are the records on gear performance, instrument settings, or techniques that are essential to interpreting the results.

5.4.5 Oceanographic, hydrographic, and meteorological observations

Changes in fish behaviour and distribution can be predicted if they can be related to predictable features of the environment. For this reason oceanographic, hydrographic and meteorological data are usually routinely collected on the survey. Spaces for recording some of them are provided on Figure 10. In the Regional Fisheries survey, meteorological information was recorded on a separate station log (Figure 12). It may sometimes be possible to make provisions for both oceanographic and meteorological observations on a single record form.

REGIONAL FISHERIES SURVEY

STATION LOG

F.R.V.

Time Cast Off	
Time Moored	
Sheet Serial	
Cruise	
Date Start	
Date End	

Station 1.	Time Start 2.	Time Finish 3	Latitude 4.	Longitude 5.	6.	Sounding (m.) 7	Wind F./<° 8	Sea 9.	Swell 10.	Cloud 11.	Gear/Remarks 12.

Duration (Days)	
Distance (N. Miles)	

NOTES - All entries must be made in HB pencil. The date is to be inserted across the columns. Position by observation, or other fix, to be indicated by an asterik in column 6. Duration and distance to be entered at the end of the cruise. Queries should be addressed to the Scientist-in-Charge, who accepts responsibility for the accuracy and adequacy of the entries. ALL TIME TO BE G.M.T.

Signed .... Master

Accepted .... Scientist-in-Charge

Figure 12. Station log used in FAO Regional Fisheries Survey

The maximum and minimum depth or mean depth observed during fishing is one of the most important hydrographic observations to be made in demersal fish surveys. Distribution of fish, catch rates and certain biological characteristics can usually be related to depth.

Other variables likely to influence availability or distribution are also recorded. Differences in dissolved oxygen, temperature, thermocline depth, salinity, and bottom type may often be reflected in the species composition, catch rates and biological sampling results.

The techniques of measurement and recording of observations on the physical and chemical environment have been detailed by Laevastu (1965).

5.5 Catch information

The object of catch information is to establish distributional patterns and abundance (relative or absolute) of the fauna sampled. The details of catch information recorded will vary with cruise objectives and observations made for species captured at given stations will vary depending on the sampling priorities. However, it will be important to establish strict observation rules at the beginning of the survey and to ensure that they are followed at all stations.

The minimum requirement for catch records is some measure of the size of the catch. As noted earlier, direct weighing is rarely practicable, especially with large catches. The most frequently used and satisfactory observation is measurement of catch volume, usually in units of standard sized "baskets" or "boxes". The volume unit chosen should be standardized for the survey and must be large enough so that there are appreciable numbers of fish per unit volume. A satisfactory calibration of weight per volume unit for different species can usually be made at the beginning of the cruise and can thus provide a conversion factor for determining an index of weight of catch.

Often, in small or moderate sized catches, a complete enumeration of the catch is made in the course of other observations, such as length compositions. In large catches, however, it may be necessary to sample only a subset of the unit volumes. The problems of sampling the catch have been studied by Pope (1956), Westrheim (1961), Paloheimo and Dickie (1963), and Gulland (1966). The results show that an initial sorting by species is almost always required for accuracy in sampling. Within species, it is furthermore necessary to ensure that sampling is only done when there is an appreciable number of volume units to choose from. Otherwise, complete measurement or enumeration is necessary. The requirement will, of course, vary with the size range of the species involved. For guidance, the original papers should be consulted.

A record of the volumes or estimated weights of the catch by species is customarily attached to the record of each of the stations made during the survey. The recording form used by the West African Regional Fisheries Survey is the bottom part of Figure 10. Completing it presents no special difficulties. A sample of the form used for demersal fish catches by the U.S. Bureau of Commercial Fisheries at Seattle is given in Figure 13. The latter has a number of advantages. It is printed on the back of the station record (Figure 14), saving the effort of filling in the station identity information a second time and ensuring that the two basic records do not become separated. Furthermore, a space is provided on the form for entering species code numbers. The completed sheet is thus ready for entry into an ADP system without recopying.

In addition to the size of catch by species, the information most generally useful in describing the catch to both the industrial user and the scientist is the length composition. In small or intermediate sized catches, it is usually possible and most desirable to measure each fish. This procedure gives at the same time a complete enumeration which is useful for deriving estimates of the average weight of the fish caught.

SEATTLE EXPLORATORY FISHING AND GEAR RESEARCH BASE
DEMERSAL CATCH FORM

1-2	3-5	6-7	8-13		
VESSEL	CRUISE NO.	HAUL NO.	DATE	LORAN (START)	LORAN (END)

14-17	18-22						23-26	27-30
LAT. (START)	LONG. (START)	LAT. (END)	LONG. (END)	BOTTOM DEPTH	START	END	MIN.	MAX.

		31-32		33-34			35-36			37-39			
TIME (ST)	START	OUT	HAUL	DURA.	IN	DIST. FISHED	N.M	TEMP. °C	SURF.	BOTTOM	REV. TH. #	BT GRID #	BT. SLIDE #

	40-44		45-47		48
BOTTOM SALINITY	0/00	BOTTOM TYPE	DESCRIPTION	CLOUD COVER	FRACTION

	49-51	52-54	55-57	58-60	61-62
GEAR OPERATION	SCOPE	R.P.M.	GEAR TYPE	DOORS & ACCESS.	GEAR PERFORMANCE

			63			64
SOUNDER	MODEL	RANGE	VOL.	PULSE	BLOCK	TRACE DESCRIPTION

WEATHER ______________________ SEA CONDITIONS ______________________

REMARKS

VESSEL / CRUISE NO. / HAUL NO. / YEAR / MO. / DAY / LAT. / LONG. /

	2			5		7		9		11		13				17					22

BOTTOM DEPTH MIN. / MAX. / TIME OUT / DURATION / DIST. FISH. / BOTTOM TEMP. / BOTTOM SALINITY /

			26				30		32		34		36			39					44

BOTTOM TYPE / CL. CV. / SCOPE / R.P.M. / GEAR TYPE / DOORS ETC. / GEAR PERF. / SD. / TR. /

		47	48			51			54			57							

Figure 13. Catch form used by Seattle Exploratory Fishing and Gear Research Base

	65 66 67 68 69	70 71 72 73 74 75	76 77 78 79			
SPECIES	CODE NO	WEIGHT (nearest 1/10 lb.)	NUMBERS	WEIGHT RANGE	LENGTH RANGE	REMARKS
Haul Card	--	--	--	--	--	--

Figure 14. Station record used by Seattle Exploratory Fishing and Gear Research Base

In large catches it may again be necessary to sample for both total number and length composition. The papers cited above discuss this problem from the point of view of obtaining a representative sample of the catch, the accuracy of the length measurement, and the number of size-classes which should be distinguished. In general, it is desirable in sampling to measure the fish from a randomly selected set of "baskets". If a separate record is kept of the contents of each basket, it permits determination of the statistical reliability of the sampling.

Choosing an appropriate length measurement is a matter of considerable importance.[2] The most commonly used measures are fork or total length measured to the "nearest centimeter" or to the "centimeter below". Because many resources are of an international nature and often data from various sources have to be pooled, several regional commissions and working groups have recommended standardization of length measurement for various species (e.g., ICES, ICNAF, CARPAS, GFCM, Tuna Working Group on Measurements). These recommendations in general suggest measurement of total length for most species (fork length for tuna type species) and recording of the measurements to the full unit (cm or, for small species, ½ cm) below (i.e., 26.9 cm, when recorded in cm groups, is recorded as 26). Appropriate measuring boards should be used, and lengths tallied for each interval. Using such recordings, the analyst is permitted considerable flexibility in the compilation and reporting of the data by length classes.

With species which show a significant sexual dimorphism, it may be necessary to separate males and females of species in the size-composition records. In some species, especially the large pelagic species, there may also be differential vulnerability of sexes to the sampling gear. Any such situations must also be taken into account in compiling and classifying catch records. The example form, attached as Figure 15, requires a sorting of the total catch into males and females as well as maturity classes prior to length measurement. More often, the forms are simpler needing only spaces for cruise and set identification, a column of numbered length classes, and spaces for the tally (see Figure 16).

5.6 Special biological information

Important information on the long-term prospects for exploitation of fish communities may be obtained from special biological observations taken on resource surveys. The age-composition, racial or spawning group characteristics, stages of sexual maturity, and stomach contents are among the most commonly useful.

It is worth noting here that age information is of particular importance and every possible consideration should be given to making provision for it in the data collecting and analysis. It can be used to derive growth and recruitment patterns and mortality rates, information indispensible to judging long-term fishery prospects. Variations in the age composition can also be useful in interpreting stock distribution and movements and thus have direct application to planning of commercial fishing strategies.

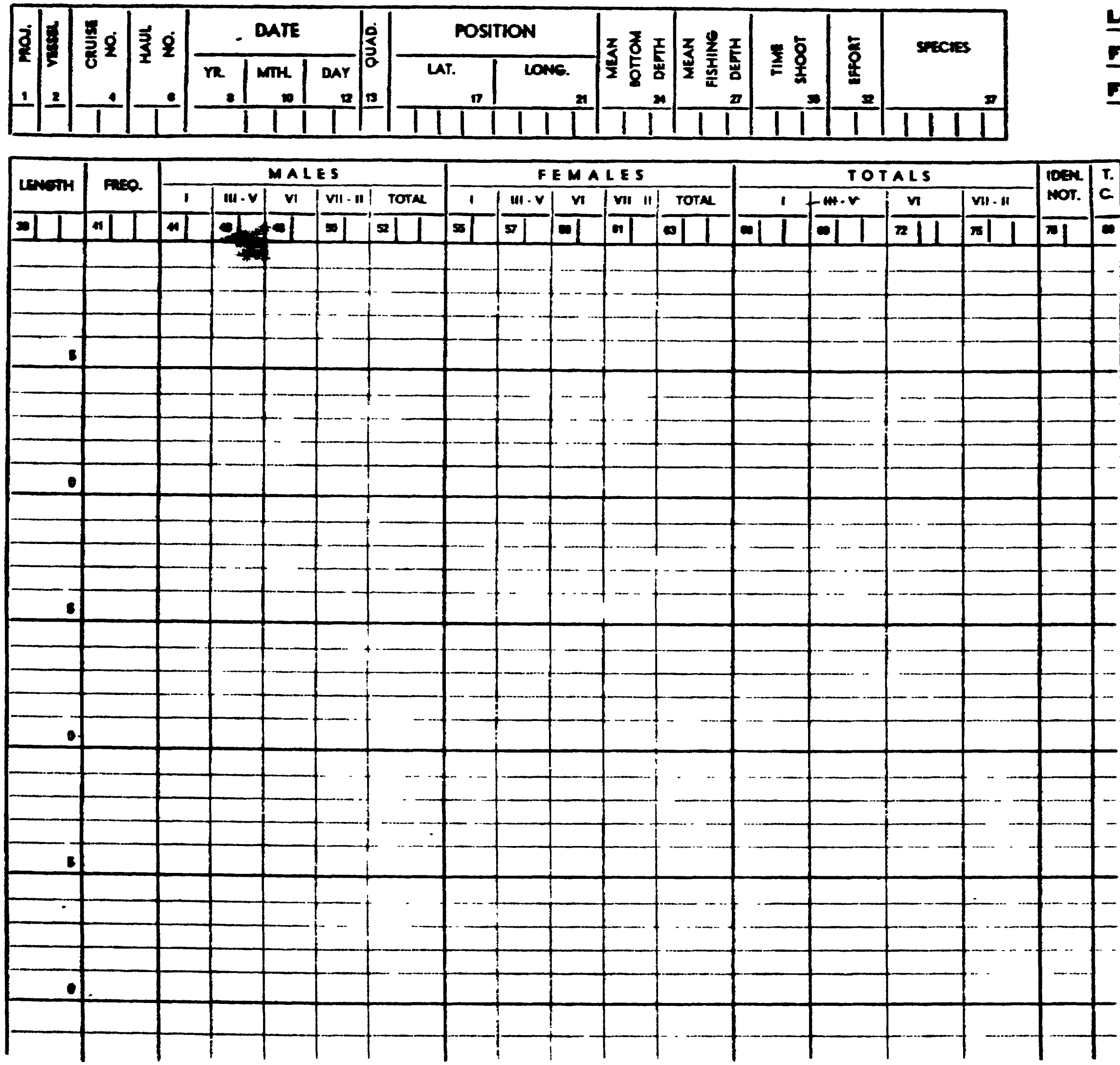
In most cases, catches made on fishery resource surveys will be too large to permit a complete enumeration of these special characteristics and sampling must be done. While it is possible to sample the catch for each of the special biological observations, such independent sampling is generally wasteful of observational effort. Where the species to be studied is at the same time being measured for length composition, it is much more efficient to establish a set of strata, based on a series of length-classes, and to carry out the biological sampling within these strata. In the case of most species, it will be generally satisfactory to establish some five or six length strata (consisting of five or six centimetre ranges, for example) and to sample a certain number of fish within each stratum. For example, it may often be convenient to take the first five fish from each size stratum as they are measured, and to isolate them for further observation.

2/ Recommendations for the standardization of length measurements for various species have been made by both ICES and ICNAF.

Length

Frequency

Form.



PROJ.	VESSEL	CRUISE NO.	HAUL NO.	DATE			QUAD.	POSITION		MEAN BOTTOM DEPTH	MEAN FISHING DEPTH	TIME SHOOT	EFFORT	SPECIES
				YR.	MTH.	DAY		LAT.	LONG.					
1	2	4	6	8	10	12	13	17	21	24	27	30	32	37

LENGTH	FREQ.	MALES					FEMALES					TOTALS				IDEN. NOT.	T. C.
		I	III - V	VI	VII - II	TOTAL	I	III - V	VI	VII - II	TOTAL	I	III - V	VI	VII - II		
38	41	44	46	48	50	52	55	57	59	61	63	66	69	72	75	78	80
5																	
0																	
5																	
0																	
5																	
0																	

Figure 15. Data form for collecting length frequency information

SPECIES________________________________ CRUISE ____________________

Length in cm. STATION____________________

Lnth		Lnth		Lnth		Lnth	
5		32		59		86	
6		33		60		87	
7		34		61		88	
8		35		62		89	
9		36		63		90	
10		37		64		91	
11		38		65		92	
12		39		66		93	
13		40		67		94	
14		41		68		95	
15		42		69		96	
16		43		70		97	
17		44		71		98	
18		45		72		99	
19		46		73		100	
20		47		74		101-105	
21		48		75		106-110	
22		49		76		111-115	
23		50		77		116-120	
24		51		78		121-125	
25		52		79		126-130	
26		53		80		131-135	
27		54		81		136-140	
28		55		82		141-145	
29		56		83		146-150	
30		57		84		151-155	
31		58		85		156-160	

Figure 16. Data form for collecting length frequency information

In preserving the biological observation data, it is usually best to make up a single record form on which all the details can be entered for each fish. These data forms must, of course, have a space in which to identify the survey and set number. The individual length must be recorded, along with the identifying body parts such as otoliths, scales, or stomach contents, preserved for further study ashore. Records of body condition, maturity stages, parasites, etc., can also be entered routinely. If a space is provided on the sheet for later entry of age readings, stomach contents identifications, etc., the form may then be used directly and conveniently for data processing. If space is also provided on the sheet for coding of the recorded observations, the sheet will be a convenient source document for ADP.

Special sampling considerations which should be borne in mind in collecting the biological data as a basis for calculation of vital population parameters are discussed by Jones (1956) and Beverton and Holt (1956). Special consideration of appropriate biological information to be recorded is given in the FAO Manual of Sampling and Statistical Methods for Fisheries Biology (Gulland, 1966).

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1967

6. DATA ANALYSIS AND REPORTING

In this chapter we have considered some commonly used methods of data analysis and reporting mainly for fishing surveys. Similar procedures are generally applicable for acoustic surveys.

Communicating results of fishing surveys may begin aboard ship; e.g., radio broadcasting of results to the fishing fleet can be made at specified times. This information may then be published in local newspapers and trade journals. This procedure has often been used when a fishing capacity is available to respond to favourable results. If several survey vessels operate in association with a fishing fleet it is possible to communicate jointly collected hydrographic and biological information (via radio) to a national data processing centre. Pertinent observations can then be summarized on charts and quickly transmitted back to the fishing fleet in the form of facsimile reports.

Mimeographed reports (cruise reports) giving preliminary results of field surveys are often issued after completing an individual cruise. Such reports should at least give information on:

(1) major cruise objectives;

(2) dates and area of operation;

(3) track line followed;

(4) stations occupied;

(5) sampling gear deployed;

and should include a short narrative concerning important observations and results. The mimeographed reports, which are sent to the news media, fishing communities, and research organizations, serve to document the activity and disseminate information concerning field activities.

Regardless of whether a report is prepared for a trade magazine, informal government circular, or for the scientific community, the use of "fishing logs" is a common means for disseminating information on fisheries surveys. At times, they are made a part of the cruise report. Such logs may incorporate the basic information concerning time and localities for sampling, general meteorological and hydrographic observations, and catch results achieved from the most important species taken. The use of fishing logs for distributing information retrieved during fishery exploration is a recommended procedure. The fishing log does not require a value judgement on the part of the reporter or investigator concerning the commercial possibility for using defined resources. It is only a tabulated record of important observations made at specific localities. The reader may make his own interpretation on the scientific or industrial importance of the observations given in the fishing log. The logs may be reproduced in mimeograph form, separated from or as a part of the cruise report, and distributed to members of the fishing community or interested groups.

An effective means for communicating results of surveys to fishermen has been developed by the U.S. Bureau of Commercial Fisheries Exploratory Fishing and Gear Research Base, Seattle. Master charts showing sub-areas studied are prepared (Figure 17). For each sub-area, transparent overlay charts (Figure 18) are made illustrating the actual course and length of any tow (sampling station). The transparent overlays may be superimposed on the local sailing charts as they are made to the same scale. Hence, the skipper may quickly take off the position information. Each drag shown on the overlay has an identification number which is cross-referenced with the fishing log (Figure 19).

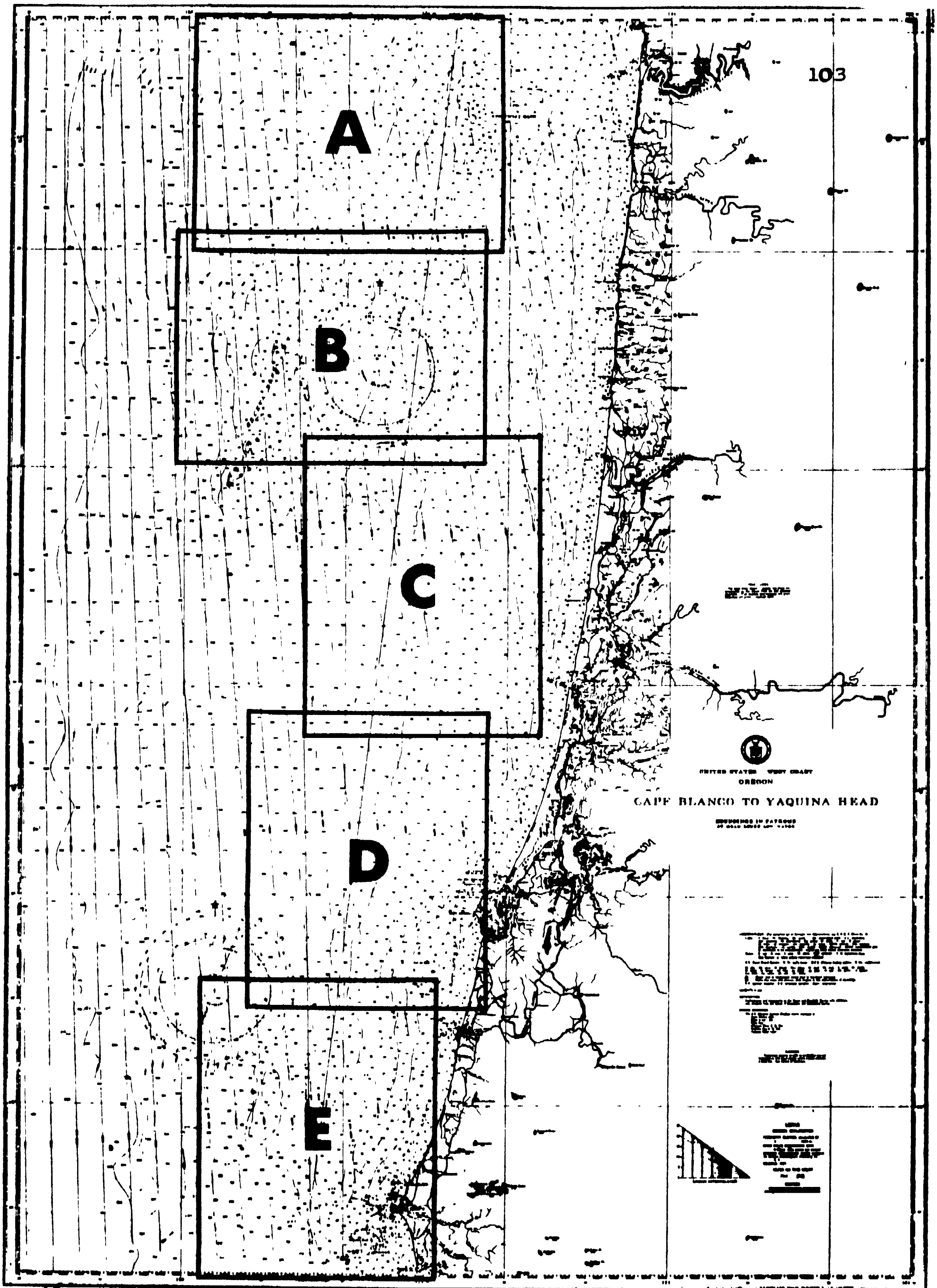


Figure 17. Sailing chart showing sub-areas investigated. Overlays are used to identify specific sub-areas which are subsequently expanded to show specific station data (see Figure 19)

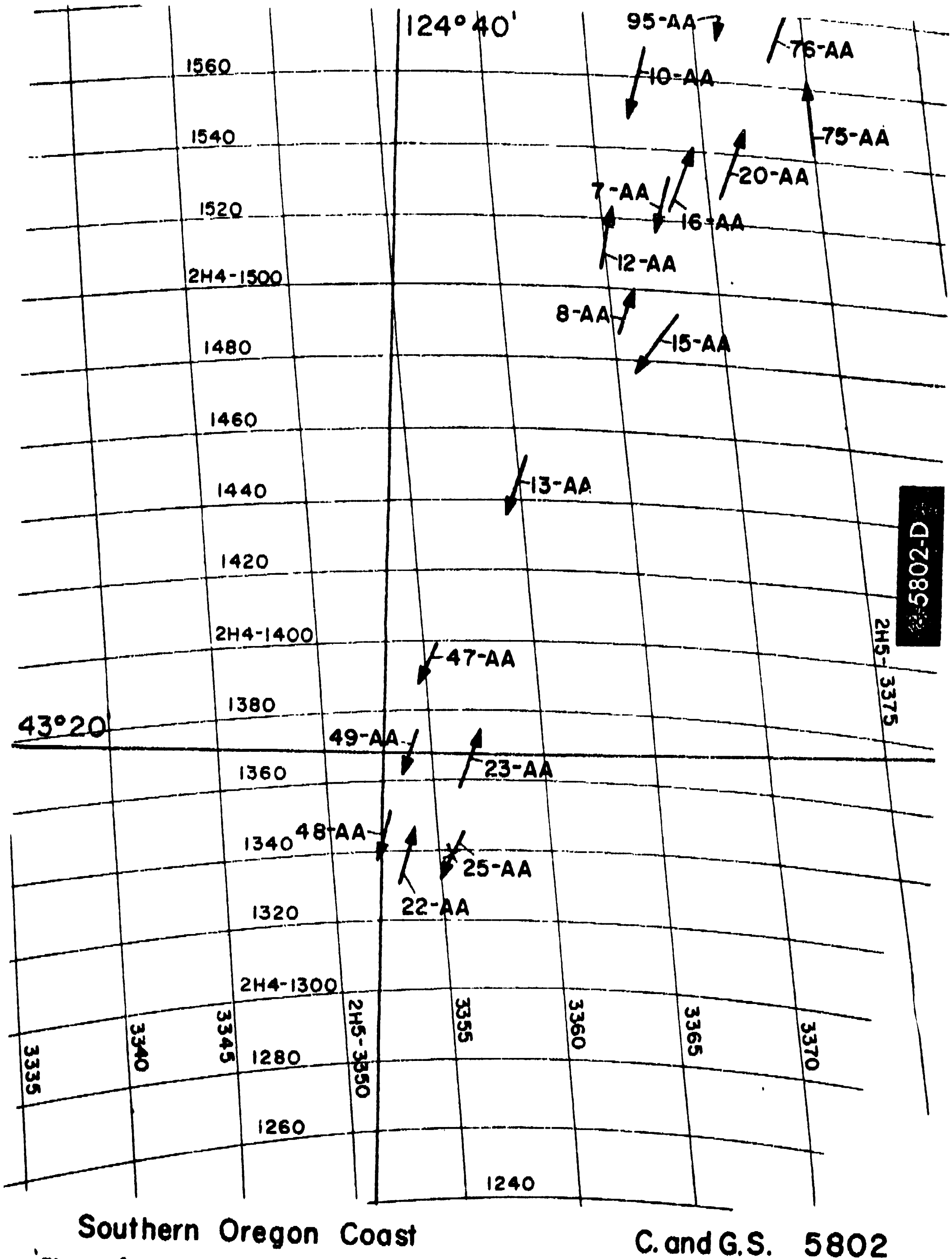


Figure 18. Transparent overlay from showing position and direction of drags made in sub-area D (see Figure 17)

"AA"
Cruise No. 48
Gear: 43 foot Gulf of Mexico shrimp trawl (ST)
Publication: Ronholt, Lael L. and Austin R. Magill (1961)
Biological Observations and Results of the 1960 John N. Cobb
Exploratory Shrimp Cruise off the Central Oregon Coast
Research Briefs, Fish Commission of Oregon, Vol. 8, No. 1 pp. 31-46, August

STN. NO	GEAR	DATE	START Latitude	START Longitude	END Latitude	END Longitude	DEPTH RANGE FATHOMS	LORAN START 2H4	LORAN START 2H5*	LORAN END 2H4	LORAN END 2H5*	REMARKS	PUBL. DRAG NO.
7-AA	ST	9/29/60	43°33'.2	124°31'.4	43°31'.9	124°31'.8	87-86	1533	3368	1517	3367	1# pink shrimp	1
8-AA	ST	"	43°29'.6	124°32'.8	43°30'.6	124°32'.5	86-85	1487	3365.5	1498	3366	35# Dover 200# pink shrimp	2
10-AA	ST	"	43°36'.2	124°32'.3	43°34'.7	124°32'.7	95	1568	3368	1548	3366.5	60# hake 20# pink shrimp	3
12-AA	ST	9/30/60	43°31'.2	124°33'.5	43°32'.6	124°33'.2	95	1505	3364.5	1523	3365.5	70# dog fish 45# pink shrimp	4
13-AA	ST	"	43°26'.7	124°35'.7	43°25'.4	124°36'.3	96	1452	3360	1436	3359	10# pink shrimp	5
15-AA	ST	"	43°30'.0	124°31'.1	43°28'.8	124°32'.3	74-75	1494	3368	1477	3366	1# pink shrimp	6
16-AA	ST	10/ 1/60	43°32'.4	124°31'.3	43°33'.9	124°30'.8	85-84	1522	3368	1541	3369.5	21# Dover 140# pink shrimp	7
18-AA	ST	"	43°40'.8	124°29'.8	43°39'.1	124°29'.9	83	1626	3372.5	1606	3371.5	Water haul	8
20-AA	ST	"	43°32'.7	124°29'.7	43°34'.2	124°29'.0	75	1527	3370.5	1547	3072	16# star fish 30# pink shrimp	9
22-AA	ST	10/ 3/60	43°16'.9	124°39'.3	43°18'.2	124°39'.0	89-85	1330	3353	1346	3354	140# Dover 40# pink shrimp	10
23-AA	ST	"	43°19'.2	124°37'.6	43°20'.4	124°37'.0	79-80	1358	3356	1375	3357	150# Dover 30# pink shrimp	11
25-AA	ST	"	43°18'.2	124°37'.5	43°17'.0	124°38'.2	75-76	1345	3356	1332	3355	Snag	12
33-AA	ST	10/ 4/60	43°04'.4	124°42'.5	43°05'.6	124°41'.4	94-96	1183	3346.5	1194	3348	70# Dover 280# pink shrimp	13
34-AA	ST	"	43°05'.6	124°41'.4	43°06'.7	124°41'.0	95-94	1193	3348	1208	3348.5	50# Dover 520# pink shrimp	14
36-AA	ST	"	43°04'.8	124°41'.1	43°05'.8	124°40'.7	90	1185	3348	1195	3349	105# rockfish 390# pink shrimp	15
38-AA	ST	10/ 5/60	43°06'.9	124°40'.4	43°08'.3	124°40'.3	90-91	1210	3350	1225	3350	150# Dover 180# pink shrimp	16

* All 2H5 are approximate readings, use 2H4 and depth soundings or Longitude and Latitude readings

DATA

Figure 19. Log information correlated to sub-areas shown in Figure 18

DATA

"AA"
Cruise No. 48 (cont'd)

STN. NO.	GEAR	DATE	START Latitude	START Longitude	END Latitude	END Longitude	DEPTH RANGE FATHOMS	LORAN START 2H4	LORAN START 2H5*	LORAN END 2H4	LORAN END 2H5*	REMARKS	PUBL. DRAG NO.
40-AA	ST	10/ 5/60	43°03'.2	124°44'.7	43°04'.5	124°43'.9	105	1172	3343	1186	3344	60# Dover sole 0# shrimp	17
42-AA	ST	"	43°02'.7	124°46'.3	43°02'.1	124°45'.0	95	1169	3340.5	1160	3342.5	70# rockfish 0# shrimp	18
44-AA	ST	"	43°01'.7	124°44'.0	43°02'.8	124°42'.8	89-91	1151	3343.5	1164	3346	110# Dover sole 150# pink shrimp	19
47-AA	ST	10/ 7/60	43°22'.5	124°38'.5	43°21'.6	124°39'.0	95-97	1398	3356	1388	3354.5	170# Dover sole 180# pink shrimp	20
48-AA	ST	"	43°20'.5	124°39'.1	43°19'.4	124°39'.4	90	1375	3354	1362	3353.5	90# Dover sole 150# pink shrimp	21
49-AA	ST	"	43°18'.6	124°39'.7	43°17'.5	124°40'.1	89-91	1352	3353	1338	3352	90# Dover sole 30# pink shrimp	22
51-AA	ST	10/ 9/60	43°47'.5	124°16'.5	43°46'.2	124°16'.6	51-52	1719	3393	1703	3392.5	40# Dover sole 30# pink shrimp	23
53-AA	ST	"	43°42'.6	124°23'.1	43°43'.4	124°23'.2	61-63	1652	3382.5	1663	3382.5	45# Dover sole 0# pink shrimp	24
56-AA	ST	10/10/60	43°50'.6	124°31'.5	43°49'.2	124°31'.3	88-90	1749	3372.5	1732	3372.5	75# Dover sole 30# pink shrimp	25
57-AA	ST	"	43°43'.7	124°30'.6	43°44'.7	124°30'.8	88-90	1661	3372	1676	3372	40# Dover sole 380# pink shrimp	26
59-AA	ST	"	43°43'.6	124°31'.8	43°44'.5	124°32'.0	93-95	1661	3370	1672	3370	75# Dover sole 120# pink shrimp	27
61-AA	ST	"	43°46'.8	124°31'.6	43°45'.0	124°31'.4	92	1701	3371	1680	3371	Water haul	28
62-AA	ST	"	43°44'.7	124°30'.8	43°45'.9	124°31'.0	89-91	1675	3372	1690	3372	90# Dover sole 650# pink shrimp	29
63-AA	ST	"	43°46'.7	124°31'.2	43°47'.9	124°31'.3	90	1699	3372	1715	3372	100# Dover sole 150# pink shrimp	30
66-AA	ST	10/20/60	43°53'.6	124°27'.5	43°54'.9	124°27'.7	70-68	1787	3379	1803	3379	75# Dover sole 10# pink shrimp	31
67-AA	ST	"	43°55'.7	124°31'.7	43°57'.2	124°31'.5	77	1812	3373	1831	3374	50# Dover sole 200# pink shrimp	32
69-AA	ST	"	43°56'.8	124°35'.0	43°58'.3	124°34'.9	96-90	1825	3368.5	1842	3369	80# rex sole 120# pink shrimp	33
70-AA	ST	"	43°59'.7	124°37'.2	43°58'.6	124°37'.8	82-83	1859	3365.5	1845	3364	75# pink shrimp	34
71-AA	ST	10/21/60	43°55'.6	124°34'.6	43°54'.2	124°34'.0	97-102	1810	3368.5	1792	3369	30# Dover sole 50# pink shrimp	35

"AA"
Cruise No. 48 (cont'd)

STN. NO.	GEAR	DATE	START Latitude	START Longitude	END * Latitude	END * Longitude	DEPTH RANGE FATHOMS	LORAN START 2H4	LORAN START 2H5*	LORAN END 2H4	LORAN END 2H5*	REMARKS	PUBL. DRAG NO.
72-AA	ST	10/21/60	43°57'.2	124°29'.7	43°55'.8	124°29'.9	73-72	1830	3377	1813	3376	40# rex sole 400# pink shrimp	36
73-AA	ST	"	44°00'.8	124°32'.8	43°59'.7	124°32'.0	77-76	1873	3373	1860	3374	50# rex sole 60# pink shrimp	37
75-AA	ST	10/22/60	43°33'.8	124°26'.8	43°35'.5	124°27'.2	70-71	1542	3375	1563	3375	30# Dover sole 50# pink shrimp	38
76-AA	ST	"	43°35'.8	124°28'.3	43°37'.5	124°27'.5	74-71	1567	3373	1587	3375	23# Dover sole 250# pink shrimp	39
77-AA	ST	"	43°38'.6	124°28'.5	43°40'.0	124°29'.1	76-77	1600	3374	1617	3373	20# rex sole 50# pink shrimp	40
78-AA	ST	"	43°38'.7	124°31'.8	43°40'.3	124°31'.3	96-94	1600	3369	1620	3370	70# Dover sole 60# pink shrimp	41
81-AA	ST	"	43°56'.2	124°27'.8	43°57'.6	124°27'.8	68-69	1819	3379	1837	3379.5	0# shrimp 100# Dover sole	42
82-AA	ST	10/29/60	43°57'.8	124°29'.7	43°59'.3	124°29'.7	73-74	1837	3377	1855	3377.5	Water haul	43
83-AA	ST	"	44°00'.4	124°26'.5	44°01'.7	124°26'.9	68	1870	3382.5	1886	3382.5	50# rex sole 2# pink shrimp	44
84-AA	ST	"	44°00'.6	124°35'.3	44°01'.8	124°34'.2	79-76	1870	3369	1885	3371.5	200# Dover sole 2# pink shrimp	45
85-AA	ST	"	44°00'.8	124°39'.9	44°02'.2	124°38'.8	74-72	1872	3362	1889	3364	250# Dover sole 10# pink shrimp	46
87-AA	ST	10/30/60	43°56'.0	124°34'.3	43°54'.9	124°33'.7	95	1815	3369	1800	3370	100# Dover sole 40# pink shrimp	47
88-AA	ST	"	43°56'.0	124°42'.3	43°55'.7	124°44'.6	90-88	1812	3357	1810	3353	Snag	48
91-AA	ST	"	44°03'.9	124°37'.9	44°05'.3	124°38'.0	68-66	1911	3366	1929	3366	10# Dover sole	49
94-AA	ST	10/31/60	43°53'.5	124°18'.9	43°52'.3	124°19'.4	60-59	1790	3392	1775	3390.5	3# yellowtail rockfish	50
95-AA	ST	"	43°37'.9	124°29'.6	43°36'.5	124°30'.0	82	1590	3372	1573	3371	12# orange rockfish 3# pink shrimp	51
96-AA	ST	11/ 1/60	44°03'.8	124°31'.2	44°02'.5	124°31'.1	69-70	1912	3376	1896	3376	7# turbot 3# pink shrimp	52
97-AA	ST	"	44°07'.1	124°30'.7	44°06'.0	124°30'.6	65-66	1954	3378	1939	3377.5	20# rex sole 2# pink shrimp	53
100-AA	ST	11/ 2/60	44°32'.5	124°36'.5	44°31'.4	124°35'.6	90-94	2265	3376	2250	3377	1# rex	54

DATA

DATA

"AB"
Cruise No. 50
Gear: 400-mesh Eastern Trawl (OT), 42 foot chain between doors (CD)
Publication: Hitz, C.R. and D.L. Alverson (1963)
Bottomfish Survey off the Oregon Coast, April-June 1961
Commercial Fisheries Review, Vol. 25, No. 6, pp. 1-7 (Also Sept. No. 677)

STN. NO.	GEAR	DATE	START		END		DEPTH RANGE FATHOMS	LORAN				REMARKS	PUBL. DRAG NO.
								START		END			
			Latitude	Longitude	Latitude	Longitude		2H4	2H5	2H4	2H5		
17-AB	OT	4/28/61	44°37'.2	124°34'.4	44°40'.3	124°33'.5	92-89	2322	3381	2361	3384	40# lingcod 150# turbot	1
18-AB	OT	4/28/61	44°39'.0	124°32'.4	44°38'.6	124°31'.3	75-73	2346	3385	2341	3387	Hung up	2
19-AB	OT	4/28/61	44°37'.9	124°33'.3	44°35'.4	124°33'.8	89-78	2331	3383	2300	3382	Snag	3
20-AB	OT	4/28/61	44°34'.9	124°32'.8	44°34'.1	124°32'.2	76-73	2295	3383	2286	3384	Hung up	4
21-AB	OT	4/28/61	44°34'.6	124°36'.4	44°30'.5	124°36'.6	101-100	2291	3377	2240	3375	138# P.O.P. 182# turbot	5
22-AB	CD	4/29/61	44°31'.2	124°31'.5	44°34'.4	124°31'.1		2250	3384	2290	3386	Hung up	
26-AB	CD	5/ 4/61	44°33'.8	124°33'.5	44°29'.7	124°31'.3	76	2280	3381	2230	3384	Clear	
27-AB	OT	"	44°33'.3	124°33'.6	44°29'.8	124°32'.2	80-66	2274	3381	2229	3384	22# red rockfish 33# ratfish	6
29-AB	CD	"	44°11'.0	124°35'.2	44°05'.6	124°33'.5	60-67	2000	3372	1935	3373	Clear	
30-AB	CD	"	44°03'.5	124°35'.1	44°08'.6	124°36'.0	71-66	1907	3370	1970	3370	Clear	
31-AB	OT	5/ 5/61	44°10'.0	124°35'.0	44°07'.0	124°33'.8	58-64	1988	3372	1950	3373	Snag	7
32-AB	OT	"	44°12'.4	124°37'.5	44°09'.8	124°36'.2	58-62	2015	3368	1985	3370	Snag	8
33-AB	OT	"	44°08'.8	124°35'.5	44°06'.1	124°34'.3	63-66	1972	3371	1938	3372	Snag	9
34-AB	OT	"	44°07'.3	124°36'.8	44°10'.0	124°37'.2	65-66	1953	3368	1985	3368	28# rex sole 23# turbot	10
35-AB	OT	"	44°09'.2	124°39'.2	44°12'.7	124°39'.7	66-60	1975	3365	2018	3365	Snag	11
37-AB	OT	5/ 6/61	44°30'.8	124°38'.5	44°34'.2	124°37'.8	118-112	2242	3372	2285	3374	290# red rockfish 944# P.O.P	12

Many investigators report preliminary results in industrial magazines. It is common in this instance to develop a narrative describing the objectives of the investigations and to make summary statements of the general results achieved giving ranges of catch rates made of important commercial species. When this procedure is used, it is common to graphically delineate relatively high catch rates (Figure 20).

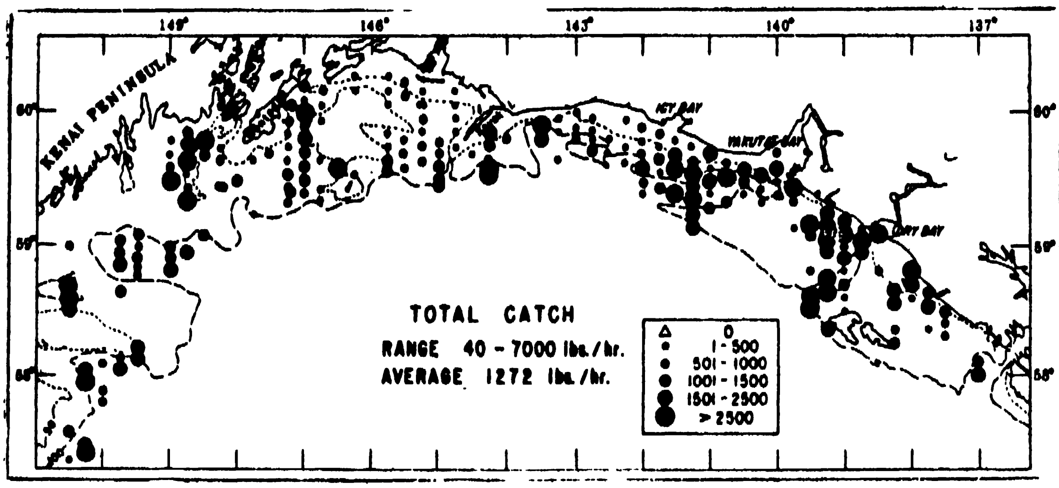


Figure 20. Relative abundance of turbot (Psetta maxima) through a section of the Gulf of Alaska (relative abundances indicated as indices per catch per unit of effort)

More formal reports should be prepared to provide information on (1) area studies and distribution of sampling, (2) animals encountered, (3) relative distribution patterns, and (4) if possible, estimates should be made of standing stocks and their potential yields. The data may also form the basis of more formal ecological studies of animal associations (Longhurst, 1965; Alton, 1970). It may also be desirable to establish minimum standing stock estimates particularly when the investigations have covered large geographic areas and standard data have been collected (Alverson, 1967). From these estimates, yield potentials can be forecasted.

6.1 Sampling distribution

Reports on the results of fishing surveys should provide the reader with a clear understanding of the area investigated and the distribution of sampling conducted within the area. This may be shown simply by graphically boxing in an area on a small-scale chart. This will allow the reader to visualise the study area in terms of larger geographic features. More detailed information of sampling stations (Figures 21 and 22), track lines (Figure 23), etc., should be made on larger scale charts. If in the process of evaluating the data, the total area is sub-divided into bathymetric or smaller geographic zones, then it is appropriate to tabularise the distribution of effort by sub-areas (Table 2).

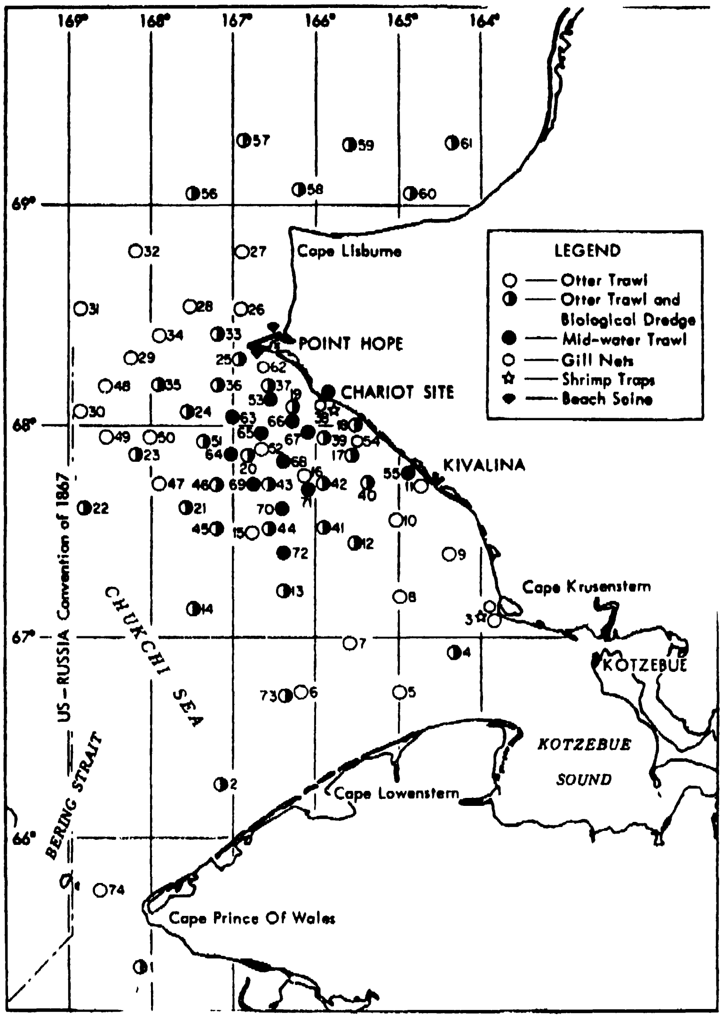


Figure 21. Distribution of sampling stations and gear deployed at each station for work conducted in Chukchi Sea in 1959

6.2 Catch composition

The composition of the catch in terms of species encountered may merely represent a listing of the scientific and common names. The area and depths studies can be subsequently sub-divided to examine the occurrence by geographic and bathymetric zones and illustrated in graphic or tabularized form (Figure 24 and Table 3). In some instances, authors list dominant species encountered again by geographic or bathymetric subdivisions; that is, those species which have constituted a major portion (e.g., 90 percent) of a particular catch (Table 4). In terms of ecological evaluation, subdividing the species complex into taxonomic groups or ecological groups (pelagic, demersal, etc.), may be desirable.

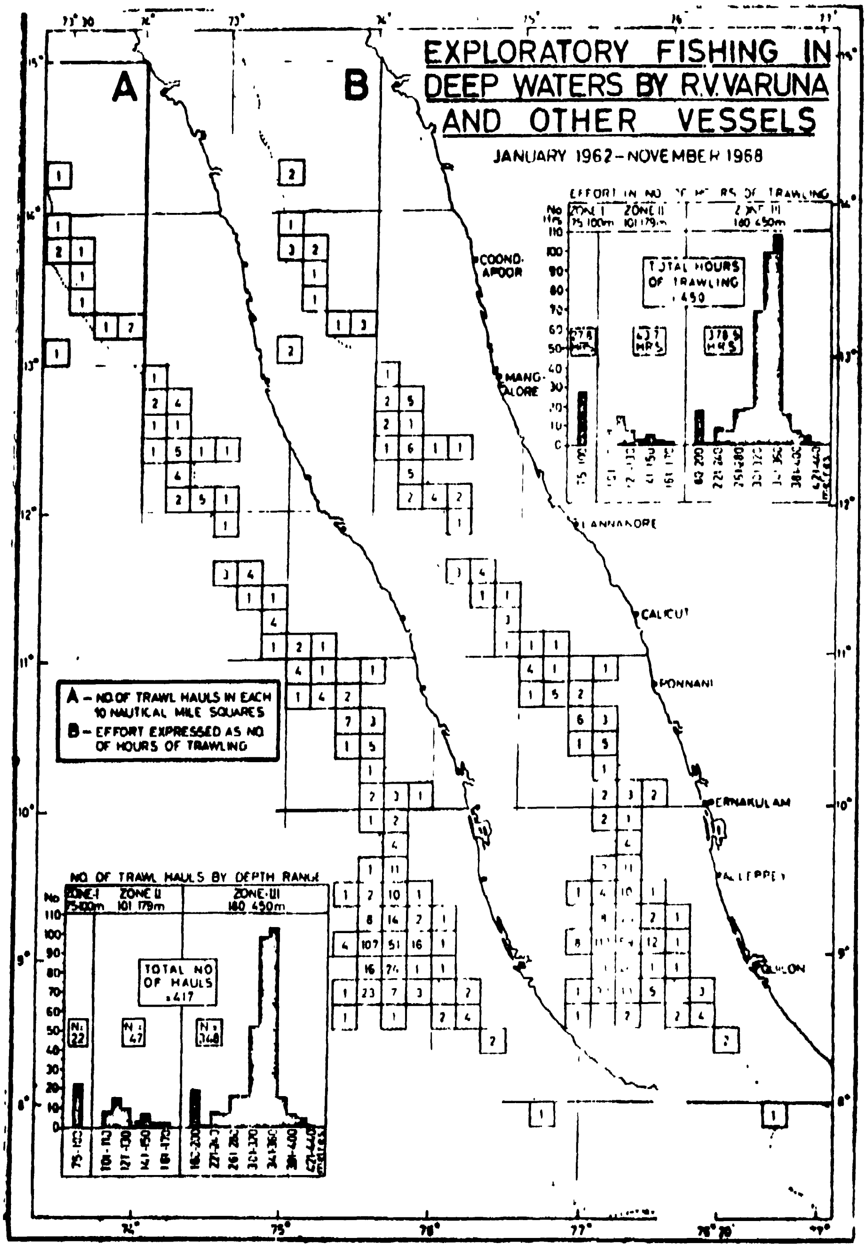


Figure 22. Exploratory otter trawling on the continental shelf edge and the upper continental slope by the R.V. VARUNA and other vessels.
A. Total number of otter trawl hauls in ten nautical mile squares;
B. Effort expended expressed as number of hours of trawling.
The frequency of occurrence of A and B in relation to depth ranges investigated is also shown. (From Silas, 1969)

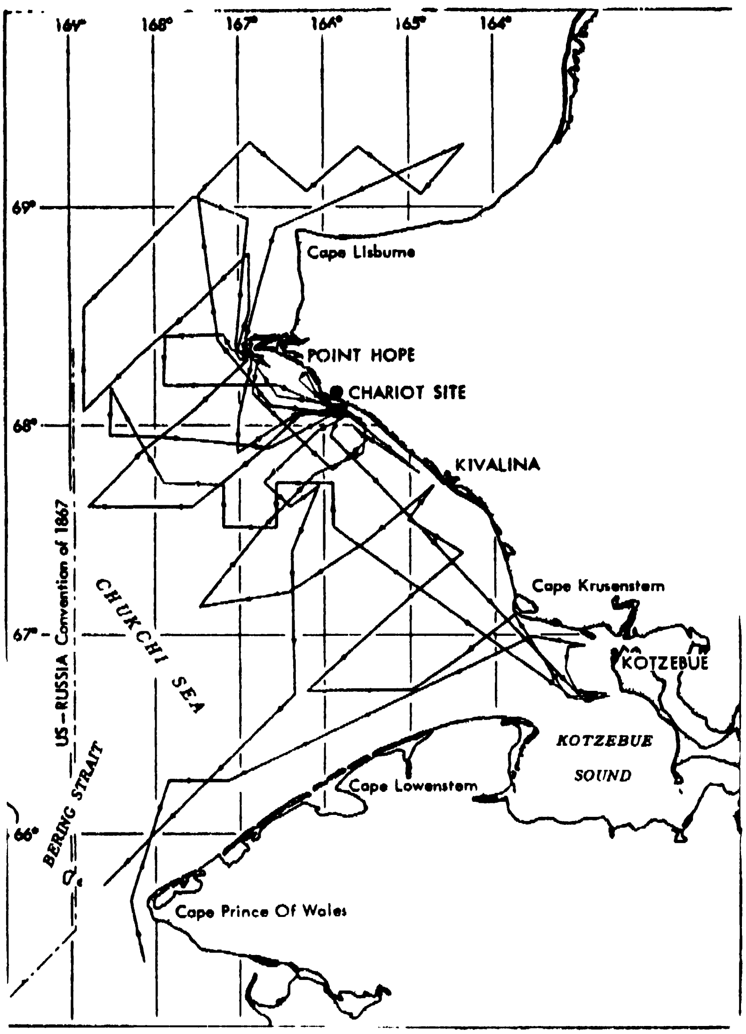


Figure 23. Track line of M.V. JOHN N. COBB explorations, 1959

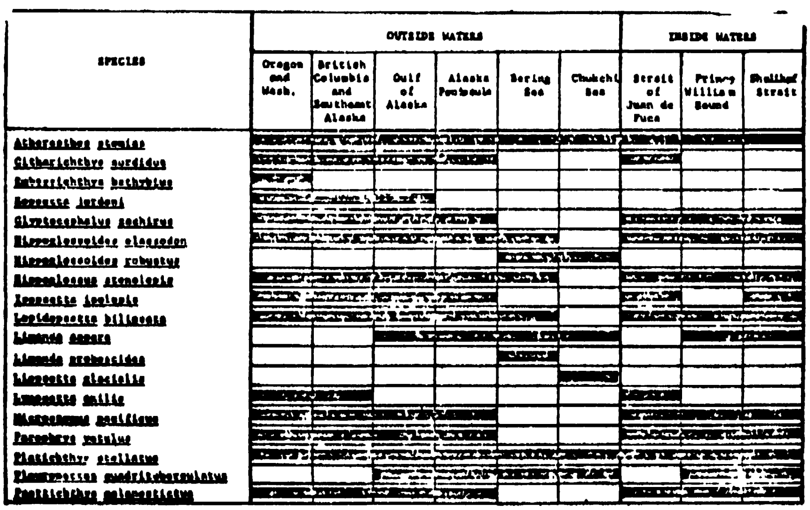


Figure 24. Occurrence of important species of flatfish by geographic area (Alverson *et al.*, 1964

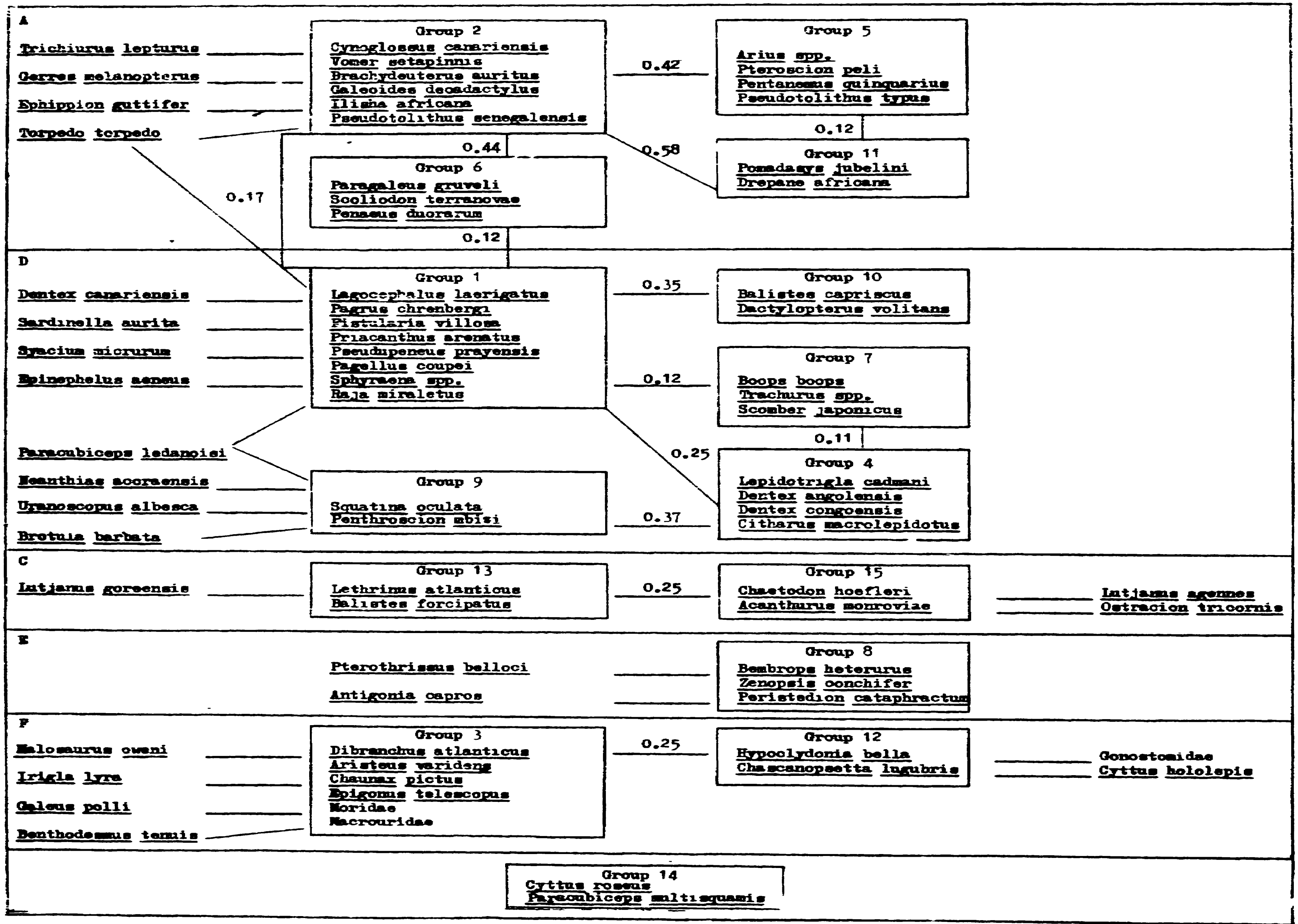
Table 2. Number of standing otter trawl drags by area and depth conducted in Northeast Pacific by U.S. Bureau of Commercial Fisheries (Alverson et al., 1964).

	Depth Interval in Fathoms								
Outside Waters	1–49	50–99	100–149	150–199	200–299	300–399	400–499	500–599	Total
Oregon-Washington	3	18	72	29	38	26	13	2	201
B.C.-S.E. Alaska	8	90	62	9	2	-	-	-	171
Gulf of Alaska	94	210	107	14	8	-	-	-	433
Alaska Peninsula	106	205	88	19	18	-	-	-	436
Bering Sea	235	-	-	-	-	-	-	-	235
Chukchi Sea	56	-	-	-	-	-	-	-	56
Sub-total	502	523	329	71	66	26	13	2	1532
Inside Waters									
Strait of Juan de Fuca	50	23	8	-	-	-	-	-	81
Southeastern Alaska	-	-	-	-	-	-	-	-	-
Yakutat Bay	-	-	-	-	-	-	-	-	-
Prince William Sound	7	-	17	1	11	-	-	-	81
Shelikof Strait	-	30	34	1	-	-	-	-	65
Sub-total	57	94	59	2	11	-	-	-	223
Grand Total	559	617	388	73	77	26	13	2	1755

6.3 Relative abundance

Relative abundance of the species, species group, or aggregate catch can be evaluated in terms of established abundance indices. In reporting relative abundance, authors quite often make lists of the dominant species encountered in a particular area either in order of weight or numbers and frequency of occurrence. This type of qualitative data is supported by tabular information giving actual catch rates, and an evaluation can be made of the relative importance of a species to the total catch or to a particular ecological or taxonomic group (Tables 5–7). General distribution in association with relative abundance can be evaluated by the frequency of occurrence at the various stations sampled (Table 8). Graphic displays of distribution patterns (both geographic and bathymetric) can provide a clear mental image of changing abundance trends. Such graphs can be designed to show changes of relative abundance between areas (Figure 25), between areas and by depth (Figures 26 and 27) or the area and depth changes for several species groups can be combined into one graph (Figure 28). Relative abundance derived from acoustic surveys can be displayed in a similar fashion; e.g., Figure 5 shows the relative abundance of echo trace and pilchard eggs. If the data have been coded and stored for ADP computer programmes, it can be used to compute density distribution charts (Figure 29). Table 9 reflects changes in catch rates in surveys conducted in the Arctic on two species of flounders relative to observed changes in temperature, while Figure 31 shows catches of bottom fish made by a survey boat in relation to bottom temperature patterns.

Table 3. Composition of species groups of demersal fish in the Guinean Trawling Survey (Williams, 1968)



A – Offshore sciaenid sub-community (at about 50 m depth)
C – Shallow water sparid sub-community (about 10–50 m)
D – Deep water sparid sub-community (about 500–200 m)
E – Deep water community (slightly overlapping D)
F – Continental Slope community (more than 200 m but slightly overlapping E

Table 4. Occurrence of demersal fishes by depth intervals. (Alverson *et al.*, 1964)

Species	Depth in Fathoms							
	1–49	50–99	100–149	150–199	200–299	300–399	400–499	500–599
FLATFISH								
Bering flounder	x							
Longhead dab	x							
Arctic flounder	x							
Yellowfin sole	x	x						
Starry flounder	x	x						
Sand sole	x	x						
Pacific sanddab	x	x	x					
Rock sole	x	x	x					
Alaska plaice	x	x	x					
Butter sole	x	x	x	x				
Slender sole		x	x	x				
Petrale sole	x	x	x	x	x			
Flathead sole	x	x	x	x	x			
Pacific halibut	x	x	x	x	x			
English sole	x	x	x	x	x			
Rex sole	x	x	x	x	x	x		
Arrowtooth flounder	x	x	x	x	x	x	x	
Deepsea sole							x	x
Dover sole	x	x	x	x	x	x	x	x
ROCKFISH								
China rockfish	x							
Quillback rockfish	x	x						
Dusky rockfish			x					
Chilipepper			x					
Vermilion rockfish			x					
Pygmy rockfish	x	x	x					
Silvergray rockfish	x	x	x	x				
Greenstriped rockfish		x	x	x				
Widow rockfish		x	x	x				
Rosethorn rockfish		x	x	x				
Black rockfish		x	x	x				
Bocaccio		x	x	x				
Canary rockfish	x	x	x	x				
Redstripe rockfish		x	x	x				
Sharpchin rockfish			x	x				
Pacific ocean perch	x	x	x	x	x			
Aurora rockfish				x	x			
Blackmouth rockfish		x	x	x	x			
Splitnose rockfish		x	x	x	x			
Yellowtail rockfish	x	x	x	x	x			
Blue rockfish	x	x	x	x	x			
Rosy rockfish		x	x	x	x			
Rasphead rockfish		x	x	x	x			
Flag rockfish		x	x	x	x			
Stripetail rockfish		x	x	x	x			
Blackthroat rockfish		x	x	x	x	x		
Channel rockfish	x	x	x	x	x	x	x	x
ROUNDFISH								
Arctic cod	x							
Saffron cod	x							
Lingcod	x	x	x	x				
Pacific cod	x	x	x	x	x			
Walleye pollock	x	x	x	x	x			
Pacific hake	x	x	x	x	x	x		
Longfin cod					x	x	x	x
Sablefish	x	x	x	x	x	x	x	x
ELASMOBRANCHS								
Spiny dogfish	x	x	x	x	x	x		
Ratfish	x	x	x	x	x	x	x	
Skate	x	x	x	x	x	x	x	x

Table 5. Pounds of flounders caught per hour of exploratory trawlings by depth interval in the Oregon-Washington region (t equals trace)

Species	Depth in Fathoms							
	1–49	50–99	100–149	150–199	200–299	300–399	400–499	500–599
Atheresthes	0	159	328	98	50	3	1	0
Citharichthys	1	10	t	0	0	0	0	0
Eopsetta	0	9	3	1	0	0	0	0
Glyptocephalus	0	49	41	26	24	t	0	0
Hippoglossoides	0	t	t	t	0	0	0	0
Hippoglossus	3	11	4	3	0	0	0	0
Isopsetta	6	0	0	0	0	0	0	0
Lepidopsetta	t	0	0	0	0	0	0	0
Limanda	0	0	0	0	0	0	0	0
Lyopsetta	0	t	t	t	0	0	0	0
Microstomus	0	145	494	402	252	28	16	23
Parophrys	4	34	3	6	t	0	0	0
Platichthys	0	0	0	0	0	0	0	0
Pleuronectes	0	0	0	0	0	0	0	0
Psettichthys	0	0	0	0	0	0	0	0
Embassichthys	0	0	0	0	0	0	1	6

Table 6. Percent (by weight) of total fish catch by indicated depth intervals accounted for by species of flounders in the Oregon-Washington region (t equals trace)

Species	Depth in Fathoms							
	1–49	50–99	100–149	150–199	200–299	300–399	400–499	500–599
Atheresthes	0	14.8	9.3	5.1	3.9	0.4	0.2	0
Citharichthys	1.3	1.0	t	0	0	0	0	0
Eopsetta	0	0.9	0.1	0.1	0	0	0	0
Glyptocephalus	0	4.5	1.2	1.4	1.8	t	0	0
Hippoglossoides	0	t	t	t	0	0	0	0
Hippoglossus	7.1	1.0	0.1	0.1	0	0	0	0
Isopsetta	13.8	0	0	0	0	0	0	0
Lepidopsetta	0.5	0	0	0	0	0	0	0
Limanda	0	0	0	0	0	0	0	0
Lyopsetta	0	t	t	t	0	0	0	0
Microstomus	0	13.4	14.0	21.1	19.3	4.1	3.1	7.9
Parophrys	9.4	3.1	0.1	0.3	t	0	0	0
Platichthys	0	0	0	0	0	0	0	0
Pleuronectes	0	0	0	0	0	0	0	0
Psettichthys	0	0	0	0	0	0	0	0
Embassichthys	0	0	0	0	0	0	0.1	2.1

Percent (by weight) of total flounder catch by indicated depth intervals accounted for by individual species of flounders in the Oregon-Washington region (t equals trace)

Species	Depth in Fathoms							
	1-49	50-99	100-149	150-199	200-299	300-399	400-499	500-599
Atheresthes	0	38.2	37.5	18.3	15.4	8.4	5.8	0
Citharichthys	4.2	2.5	t	0	0	0	0	0
Eopsetta	0	2.3	0.4	0.2	0	0	0	0
Glyptocephalus	0	11.7	4.7	4.9	7.2	0.6	0	0
Hippoglossoides	0	t	t	t	0	0	0	0
Hippoglossus	22.2	2.6	0.5	0.5	0	0	0	0
Isopsetta	43.1	0	0	0	0	0	0	0
Lepidopsetta	1.4	0	0	0	0	0	0	0
Limanda	0	0	0	0	0	0	0	0
Lyopsetta	0	t	0.1	t	0	0	0	0
Microstomus	0	34.7	56.5	74.9	77.3	91.0	90.7	79.1
Parophrys	29.2	8.1	0.4	1.2	t	0	0	0
Platichthys	0	0	0	0	0	0	0	0
Pleuronectes	0	0	0	0	0	0	0	0
Psettichthys	0	0	0	0	0	0	0	0
Embassichthys	0	0	0	0	0	0	3.6	20.9

Table 8. Percent of species occurrence in total drags indicated by depth intervals in the Oregon-Washington region

Species	Depth in Fathoms							
	1-49	50-99	100-149	150-199	200-299	300-399	400-499	500-599
Atheresthes	0	72.2	94.4	89.7	79.0	38.5	15.4	0
Citharichthys	100	27.8	2.8	0	0	0	0	0
Eopsetta	0	77.8	22.2	27.6	0	0	0	0
Glyptocephalus	0	94.4	76.4	65.5	81.6	7.7	0	0
Hippoglossoides	0	5.6	1.4	3.5	0	0	0	0
Hippoglossus	66.7	27.8	19.4	10.3	0	0	0	0
Isopsetta	100	0	0	0	0	0	0	0
Lepidopsetta	33.3	0	0	0	0	0	0	0
Limanda	0	0	0	0	0	0	0	0
Lyopsetta	0	5.6	5.6	6.9	2.6	0	0	0
Microstomus	0	83.3	91.7	100	97.4	88.5	76.9	50
Parophrys	100	61.1	20.8	24.1	0	0	0	0
Platichthys	0	0	0	0	0	0	0	0
Pleuronectes	0	0	0	0	0	0	0	0
Psettichthys	0	0	0	0	0	0	0	0
Embassichthys	0	0	0	0	0	0	38.5	50

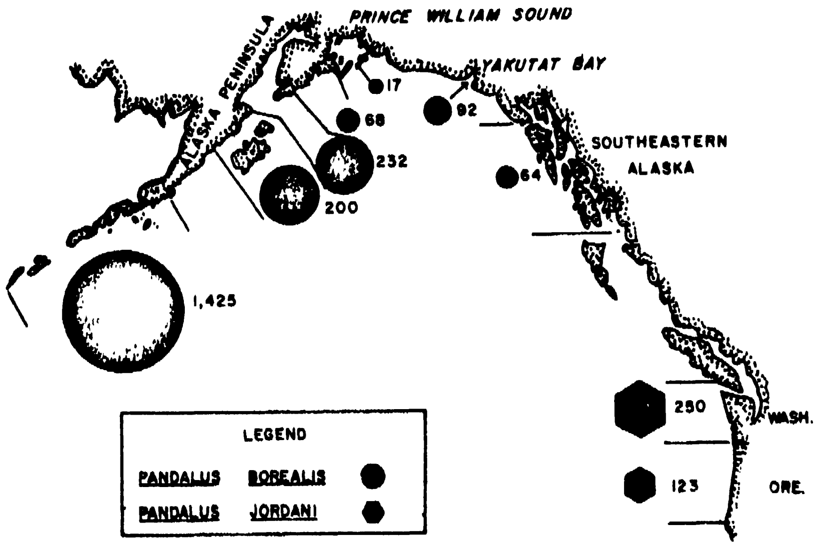


Figure 25. Average catch per 30-minutes trawling for pink shrimp taken in surveys throughout the Northeastern Pacific (Ronholt, 1963)

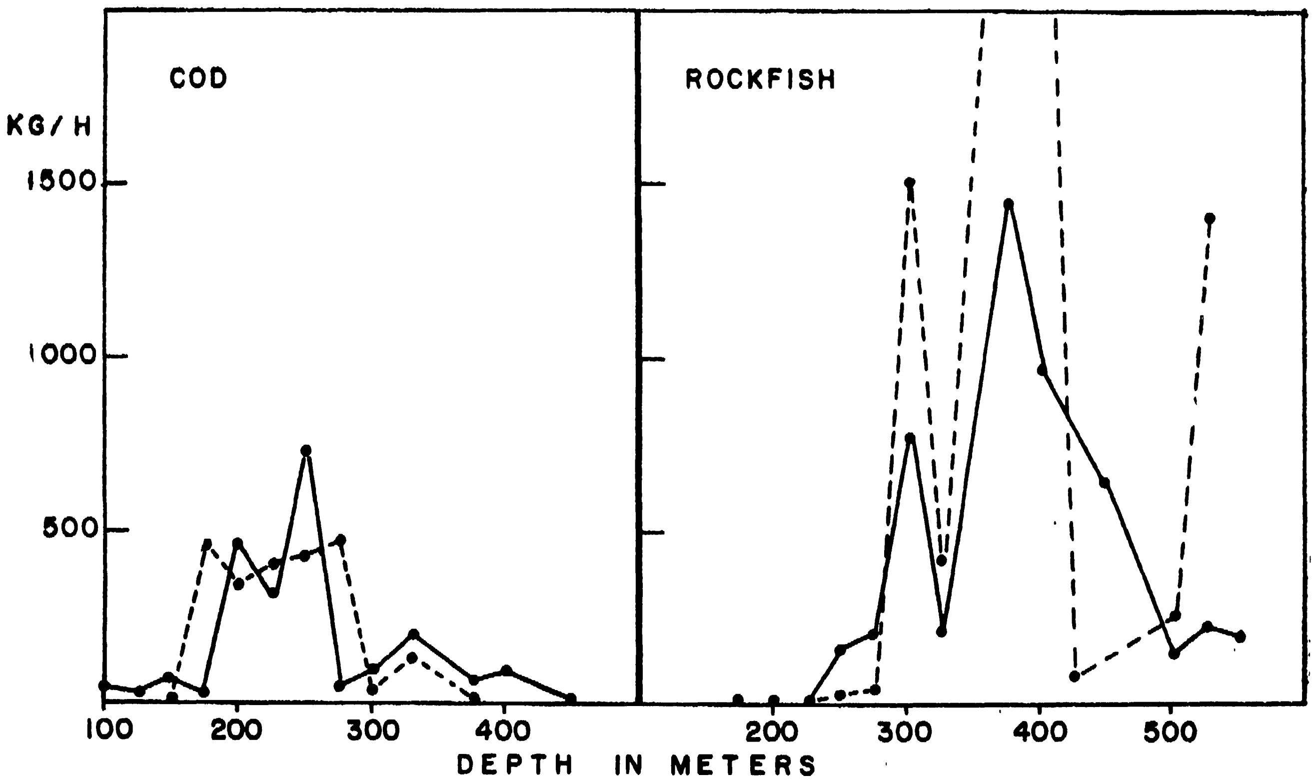


Figure 26. Yield obtained on cod and redfish in kg per hour of fishing at various depths at Labrador (dash lines) and north of the Newfoundland Banks (solid line)

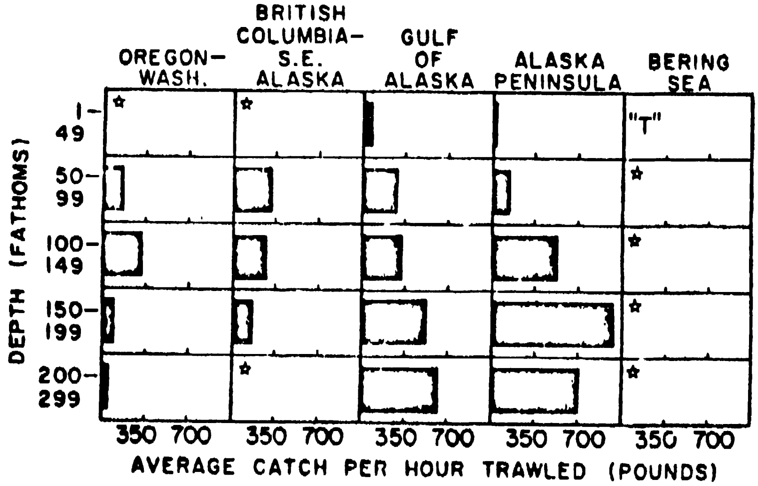


Figure 27. Pounds of turbot (Atheresthes stomias) caught per hour of trawling by geographic regions and depth zones (t equals trace; *equals inadequate or no sampling (Alverson et al., 1964)

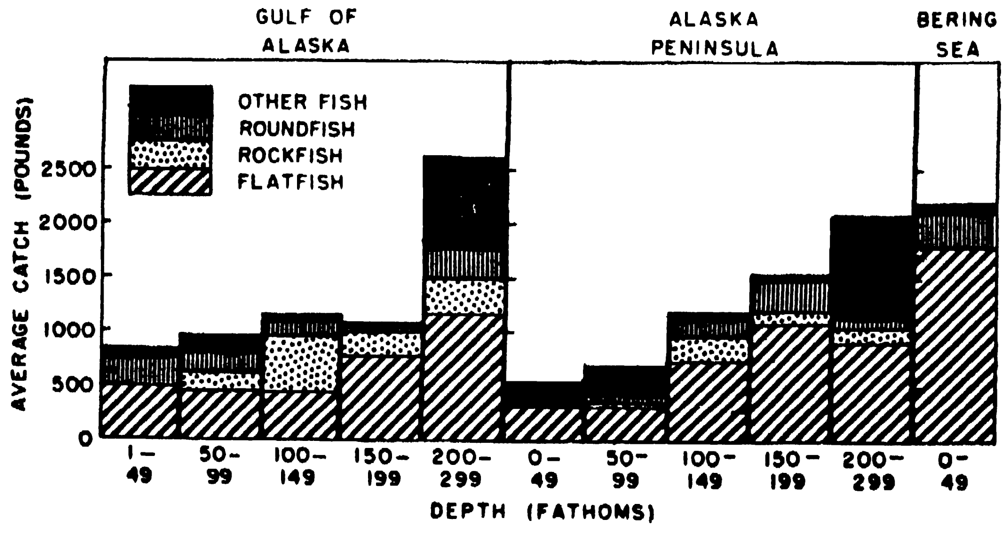


Figure 28. Average catch per hour trawling (Gulf of Alaska) for demersal fishes taken during surveys in the Northeastern Pacific (Alverson, et al., 1964)

Table 9. Distribution of Hippoglossoides robustus and Limanda aspera according to bottom-water temperature (Pruter and Alverson, 1962)

Temperature range °F	°C	Number of hauls	Number of H. robustus	Number of L. aspera
35-36	1.4-2.5	2	12	0
37-38	2.6-3.6	12	106	1
39-40	3.7-4.7	12	54	0
41-42	4.8-5.8	17	71	3
43-44	5.9-6.9	6	0	2
45-46	7.0-8.1	6	5	24
47-48	8.2-9.2	4	4	1
	Total:	59	252	31

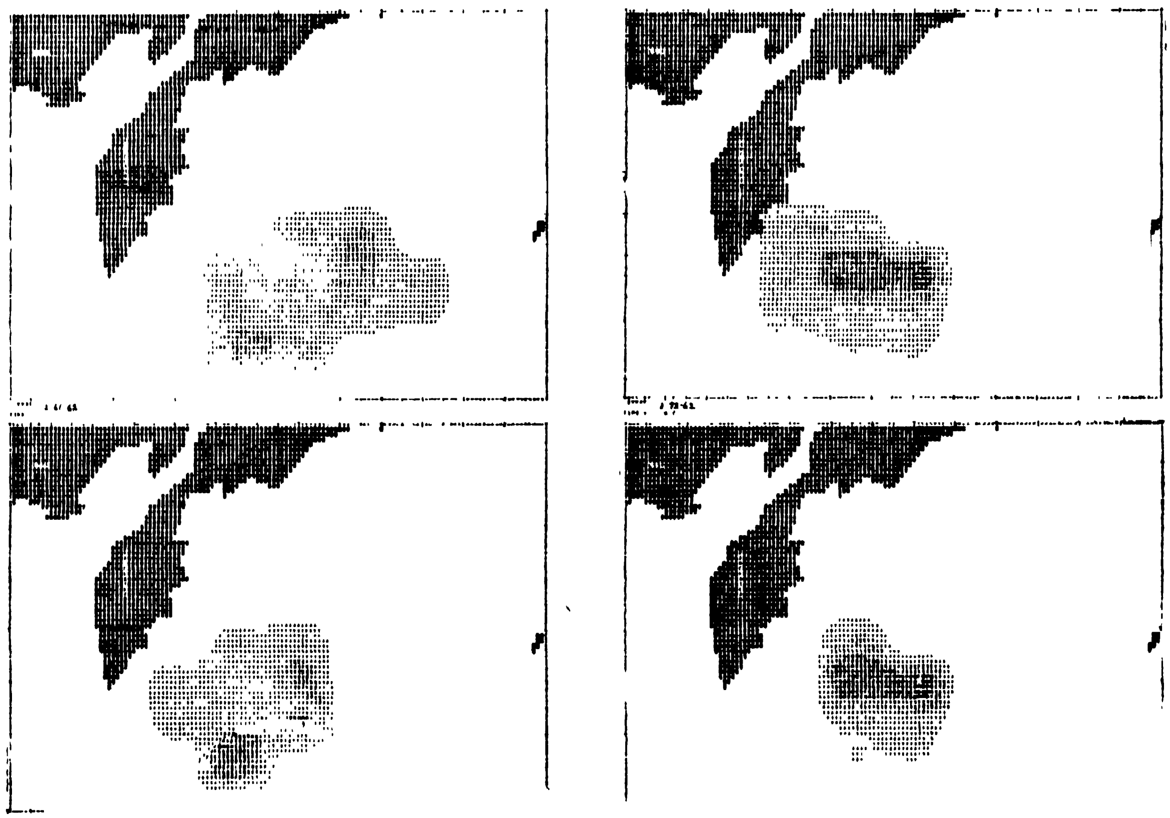


Figure 29. CPUE of 2-ocean sockeye salmon by 10-day periods from 11 May through 31 July 1962. (From Fisheries Research Institute Report, University of Washington)

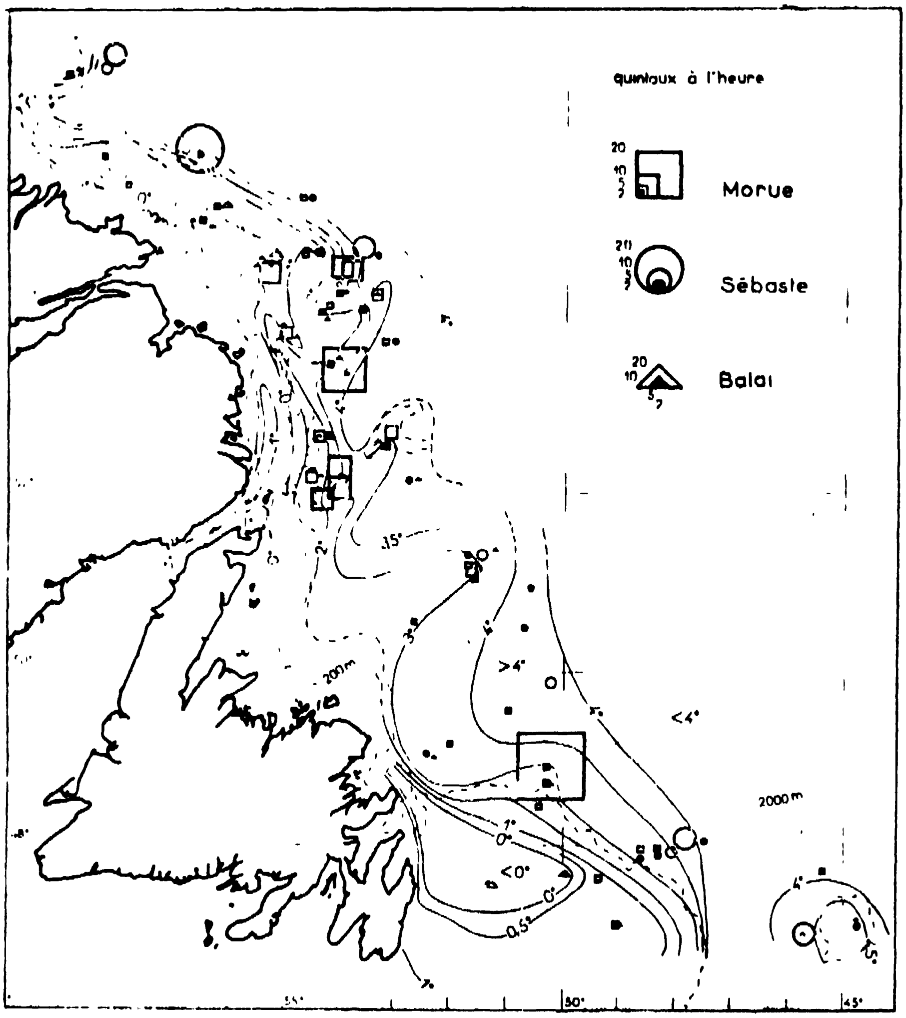


Figure 30. Distribution de la temperature sur le fond et rendement obtenu en morue, sebaste et balai (Letaconnoux et al., 1967)

6.4 Standing stock size

The techniques used to determine the standing stock for demersal fish and shellfish and the limitations of such estimates have been discussed by Alverson et al., (1964). The method is founded on the basic assumption that catch per unit of effort is a function of stock density in the area being surveyed and that changes in catch per unit of effort are directly proportional to changes in density (Ricker, 1940; Gulland, 1964). Knowing the speed at which a trawl moves, its sweep, etc., and making certain assumptions as to the efficiency of the gear, it is possible then to calculate density and thus estimate the total population of demersal fish (of sizes susceptible to the trawl) in a defined area.

The mathematical procedures for estimating standing stock by this technique are not complicated. First, the familiar equation relating population size to catch per unit of effort is:

$$\bar{P}_{W_{ij}} = C_{W_{ij}} / qf_{ij}$$

where i = ith time period; j = jth location or area; $\bar{P}_W$ = average population or standing stock in weight of the exploitable population; C_W = catch in weight; q = coefficient of catchability; f = fishing effort.

The average catch per hour for any specific depth interval or area is calculated by dividing the total catch for the interval in question by the total effort expended to make this catch. Thus,

$$\bar{P}_{W_{ij}} = \sum_{k=1}^{n} C_{W_{ijk}} \Big/ q \sum_{k=1}^{n} f_{ijk}$$

where the subscript k refers to the kth drag in the jth area.

If the average bottom area covered by the trawl per unit time in the jth area is $\bar{a}_j$ and the catch in weight per unit time in this area is C_j, then the density of fish (weight per unit area) is given by D_j, where

$$D_j = c_j C_j \Big/ \bar{a}_j$$

and c_j is the catchability coefficient (Paloheimo and Dickie, 1964). If the total bottom area in the jth area is A_j, then the total weight of the population in this area, P_j, is given by

$$P_j = A_j D_j = c_j C_j \quad A_j \Big/ \bar{a}_j$$

If there are appreciable seasonal changes in stock then the time periods can be treated separately, and for the ith period we have

$$P_{ij} = c_{ij} \ C_{ij} \quad A_j \Big/ a_j$$

The total standing stock for any region will be the sum of the standing stocks for the various sub-areas or zones forming the region.

The coefficient "c" is usually thought of as the coefficient of vulnerability for those fish of sufficient size to be retained by the trawl which are within the "area" swept by the trawl during a standard tow. In this definition the "area" includes the ground area covered by the trawl (distance of the tow × the spread of the net) up to the average headrope height. As such, the resulting estimate is restricted to that portion of the seabed and overlying water column that the gear can sample. For example, a trawl used in surveys of demersal fishes in the north-eastern Pacific had an average spread during fishing of approximately 40 ft (wing tip to wing tip) and an average vertical opening of about 6 ft. The forecast must, therefore, be limited to the zone actually sampled by the gear and does not represent an estimate of the total population under a unit surface area of the ocean. Although it can be expected to give some preliminary minimum estimate, it is particularly subject to error in evaluating species that move well up into the water column above the seabed.

For this reason, those fish above and below the area swept by the trawl, e.g. fish buried in the seabed or those distributed farther off bottom than the headrope height of the trawl, must be considered if c is to be a true measure of vulnerability. Hence, the coefficient of vulnerability (c) as denoted should be the product of two coefficients that express: (1) vulnerability of those fish that actually come within the influence of the trawl (c_h), and (2) the proportion of the total fish in the volume of water above the seabed area swept by the trawl which would come within the trawl's influence (c_v).3/ Of the two factors forming c, c_v is more difficult to estimate because it requires a fundamental understanding of the vertical density patterns of the species involved. For any of the strictly demersal species, such as flounders, which are usually close to the seabed, this value may approach 1.0. On the other hand, for those species that either burrow in the seabed and, hence, are below the zone of sampling or inhabit areas well above the ocean floor, c_v may have a relatively small value as a large percentage of the fish present over the area "swept" by the gear will not actually come under its influence.

3/ c_v might be thought of as an availability term

Under certain conditions, σ could be greater than 1.0, such as when demersal species are herded by the warps into the path of the trawl. Under these conditions, σ_h would be greater than 1.0 and σ_v close to 1.0.

This may seem somewhat paradoxical but relates to one's operational definition of the coefficient of vulnerability. Let us define σ_h as quantity or mass of fish caught by the trawl divided by the exploitable mass or weight of fish which was actually in the area (volume) swept by the trawl. As the area swept by the trawl is much smaller than the area under influence of the trawl doors and as the bridles from the trawl doors tend to herd certain species of fish into the mouth of the trawl, σ_h will be greater than 1.0 when the herding effect results in more fish (mass) captured by the trawl than was in the area swept by the trawl prior to its passing. If σ_v is near 1.0, then $\sigma_v . \sigma_h$ (i.e., σ) may exceed 1.0.

As a first approximation, one can assume that σ is equal to 1.0. With increased knowledge of behaviour of fish to the sampling gear and the degree to which they can escape an oncoming trawl, one should be able to forecast this coefficient more precisely. However, by assuming σ to be 1.0, a preliminary forecast of the standing stock size is possible. These estimates must obviously be considered as rough approximations of the exploitable resource. They are likely to under-estimate semi-pelagic species and could easily over-estimate some flatfish populations.

A similar approach may be applied to survey schooling pelagic fish which have subsequently been sampled with a trawl or seine to establish indices of abundance (density). In the study of West Coast hake, the following technique was completed to make estimates of standing stock: a series of cruises were made in which echo surveys established the distribution of hake concentrations. When aggregates were encountered during the echo surveys, "topography" of the schools was subsequently determined by a series of closely-spaced echo tracks across the concentration. Each concentration was then sampled several times to establish catch rates (using midwater trawls). Hence, a minimum density value could be established for each particular concentration. Defined areas of concentration expressed in terms of volume divided by the sampled volume could then be multiplied by the average density to establish a minimum population size (Nelson, 1970). In these circumstances, σ_v was assumed to be 1.0 when in fact it must have been considerably smaller. It, nevertheless, provided some first approximations of the exploitable stock size.

6.5 Potential production of latent stocks

Several methods are now being used to estimate the potential production from biomass or standing stock figures of latent resources. The value of any such estimates, of course, relates directly to the reliability of the forecast of the biomass as well as to the assumptions that underlie the yield models employed.

A small working group established by FAO to consider world fish potentials has suggested several approaches. This group has noted that Tiurin (1962) felt that in heavily exploited fish stocks yielding catches at or near the maximum sustainable yield, F (instantaneous rate of fishing mortality) generally is equal to or exceeds M (instantaneous rate of natural mortality).4/ If this relationship generally holds, then one can make first approximations of yield by either the Schaefer or Beverton and Holt models. We have chosen to refer to these yields as yield from exploitable biomass (YEB) rather than maximum sustainable yield. Although YEB, particularly over a certain size range, may closely approximate the theoretical maximum sustainable yield (Ricker, 1958), these two yield estimates are not necessarily similar as the calculation of YEB involves standing stocks which are based on the catch rate of the size groups selected by the sampling gear. The term YEB, however, may be more functional in that it implies variable yield possibilities with time and can be easily related to the economic usable portion of the surveyed populations.

4/ Estimates of M when unknown can be derived from maximum age (see Figure 32) if known

By the simpler Schaefer model (1954) the maximum yield, C_{max}, is achieved when the exploitable population reaches approximately one half its original or virgin biomass, B_o. Assuming $F = M$, the first approximation of the maximum sustainable catch would be: $C_{max} = 0.5\ M\ B_o$ (Gulland, 1970). If the yield tables from Beverton and Holt are used, and if we assume that we again can extrapolate from the virgin state to heavy fishing, yield can be expressed as a proportion of the virgin population. For the Beverton and Holt constant recruitment model, the relationship of C_{max}/B_o can be calculated provided age at first capture is specified. The value differs slightly depending on age of first capture and also the values of (M and K) but over the most likely range of these parameters C_{max}/B_o does not differ much from 0.4 M. Thus, we may use as a rough approximation the relationship $C_{max} = 0.4\ M\ B_o$ (Gulland, 1970). Hence, estimates based on either model will be similar.

If the above relationship between natural mortality and expected yields from known population sizes holds, we can expect most of the demersal fishes (which have relatively low natural mortality rates) sought by the major trawl fisheries of the North Atlantic and Pacific to provide yields which are a small fraction of the virgin biomass (e.g. YEB < .20 B_o). For species having high natural mortality and a rapid flux of material, as in some tropical forms, relationships between YEB and B_o may be much closer; and in extreme instances, it is possible for the yields to exceed measured standing stocks; i.e. when $M > 2.0$. The latter is common for many plankton forms but not for commercially exploited fishes.

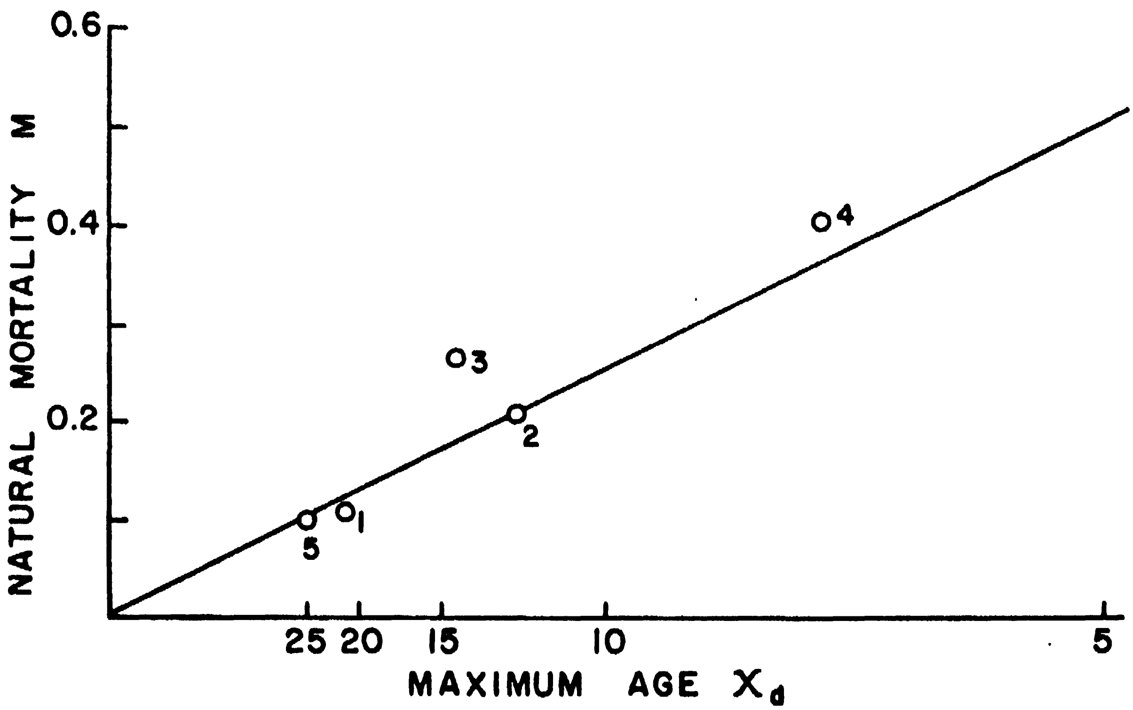


Figure 31. Relationship of natural mortality to maximum age (Tanaka, 1960)

These forecasted yield potentials based on standing stock size of any particular species represent biological potentials and not necessarily the realizable yields. They are the maximum expected yields if the population stocks could be properly and effectively used. This is seldom the case. Fisheries are not based on average geographic catch rates but operate only in those regions where catch rates are sufficiently high to allow the producer to make a profit from his operation. In many areas and depths, the density of a species may never reach high enough levels to allow economic extraction. Hence, the economic potential represents an extractive capability within or equal to the biological potential.

If estimates of the rate of natural mortality for the species under investigation are not available, one might substitute the rate of natural mortality of a closely allied species. If the life histories of the two species are similar, this approach may represent a suitable first approach for estimating yields. As information begins to accumulate on the various species being surveyed, attempts should be made to establish specific rates of growth and natural mortality for more abundant forms. If these two biological parameters can be established, yield per recruit curves can be derived along with more sophisticated forecasts of the maximum sustainable yield.

One such simulation approach for estimating the equilibrium yields to be expected from virgin populations off Oregon and Washington was employed by Pereyra and Tillman (MS, 1966) for Pacific hake and Pacific ocean perch. In their study, calculations were carried out using the "Piece-wise Integration of Yield Curves Programme - FRG 708" written by the Fisheries Research Institute of the University of Washington and described in detail by Paulik and Bayliff (1967). In this programme, approximate yield isopleths are calculated after the exponential equilibrium yield model of Ricker (1958). All instantaneous rates (natural mortality, fishing mortality, and growth) for Pacific hake were age specific, being derived from exploratory fishing data. Similar data for the Pacific ocean perch were computed using vital statistic data given by Westrheim (MS, 1950). Yield was varied by changing the age at first capture in the fishery and applying multipliers to all the individual age specific rates of fishing mortality to vary the total fishing mortality. A biomass vector was obtained giving the relative weight of the stock at each age in the absence of fishing. By combining this relative biomass vector with the estimate of standing stock of the virgin population obtained from analysis of exploratory survey data, the total weight of each year-class composing the standing stock was calculated. Back-calculating from knowledge of the selectivity of the sampling gear provided an estimate of weight at recruitment which could then be used to calculate the equilibrium yields in the usual manner.

6.6 Interpreting results

The investigator must be extra careful in interpreting the results received from any particular survey. It will be important to recognize in any evaluation the underlying assumptions and their validity. Calculated standing stock and yield will depend on the correctness of the abundance indices established by the sampling gears and whether or not the sampling patterns correctly portrayed the distribution of the animals investigated. As most sampling gears are selective in character, the size and species of fish taken will be influenced by the type of gear, the mesh size employed, the strategy in which gear is fished, etc. Even species within the size range which would theoretically be retained by the sampling gears employed may differ in their ability to escape the gear selected or in their general vulnerability to it. The species composition, size, and relative quantity of fish captured thus can be altered from that which actually occurs in nature. The degree to which the "apparent" distribution and relative abundance differs from the actual is difficult to assess. Results, therefore, should be defined in terms of assumptions and limitations and related to the sampling gear employed.

It is noted that neither exploratory surveys which employ direct sampling procedures or acoustical surveys can in themselves provide information on stock units. Hence, these data if important in a managerial sense, must be obtained through employing other investigative techniques. Finally, it is important when reporting on exploratory surveys to note the implications of time as related to the dynamic character of the surveyed resources.

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GLOSSARY

Attenuation:	the loss of intensity with range due to absorption and to scattering
A-scan display:	a display of voltage on time on a CTR
Coefficient of catchability:	ratio of fish caught, by unit effort, to the whole stock
C.R.T. (Cathode ray tube):	a two dimensional display (e.g., voltage on time) on a fluorescent screen, like a television screen
Decibel:	ratio of intensities in logarithmic units; e.g., $N = 10 \log_{10} I_1/I_2$ dB, where I_1 and I_2 are two intensities
Directivity coefficient:	the power transmitted (or received) at an angle to the acoustic axis, as a proportion of that on the axis
Echo level:	the signal received from a target or targets in dB, as expressed in the sonar equation
Echo trace:	successive signals from the same target on a paper record
Ecological groups:	fish or shellfish species belonging to the same habitat or of similar behaviour; i.e., pelagic, demersal and benthic species
Environmental features:	physical properties characterizing the environment, such as seawater temperature and salinity, type of bottom, depth, etc.
Fingernail trace:	an echo trace generated by the successive actions from a single fish which endures for more than approximately one pulse length in range
Isaac-Kidd trawl:	an undersized trawl designed to collect large plankton such as euphausiids, macrocopepods and post larval fishes
One-way propagation loss:	the loss of intensity in range due to spreading and attenuation, expressed in dB
Operational logistics:	facilities or means at the disposal of the investigators for the execution of the survey
Pulse:	the packet of energy in a single transmission, which endures for a short time (0.1-5.00 ms) and which travels through the water at 1500/m/sec (the speed of sound in water)
Reflection coefficient:	the proportion of sound reflected from the surface of a discontinuity, taking into account the characteristics of the materials
Sampling gear:	all types of fishing gear used either to identify or to estimate abundance of fish concentrations
Sampling pattern:	plan with predetermined positions of the stations or fishing operation, taking into account for instance, bottom topography, hydrographical conditions, location of fish concentrations, etc.

Search pattern: track lines or grid used, for instance, for preliminary observations on fish concentrations or suitable bottom location

Side scanner: a sonar, usually with a fan beam, which transmits a beam of the ship, so a display is formed of the ship's track and the range of the sonar

Signal counting: a procedure by which signals are counted simply from the volume sampled in one transmission

Signal-to-noise ratio: the ratio at which a signal can be detected against a background of noise (often about 3:1)

Source level: the power output of the transducer expressed in dB relative to 1µBar at a distance of 1 metre from the transducer

Station pattern: plan with predetermined positions of the stations or fishing operation, taking into account, for instance, bottom topography, hydrographical conditions, location of fish concentrations, etc.

Target strength: the signal received from a target at a distance of 1 metre as proportion of the incident signal in dB relative to that of a 2 metre sphere (0 dB)

Time varied gain: amplification to compensate for losses in signal strength due to spreading and to attenuation

Total assessment: assessment dealing with the whole fauna living in a given area

Trace counting: a procedure by which signals are counted from the volume sampled in many transmissions over a time period

Trace-to-trace correlation: correlation in time between successive signals from the same target, which distinguishes it from noise

Transducer: a device which transforms energy from mode electro-mechanical to the acoustic mode

Voltage integrator: an instrument which integrates voltage in time and displays it on a paper record or digitally

YEB (Yield for exploitable biomass): the yield a given stock may produce calculated as a function of the standing stock (in weight) of exploitable sizes.

APPENDIX I

Distribution pattern in life history of southern bluefin tuna (Shingu, 1970)

Developmental stage and yearly cycle of life	Major morphological features	Known fishing or sampling areas and seasons
Egg stage		
Pre-larval stage	With yolk sac	
Post-larval stage	Yolk sac absorbed	About 50 post-larvae of 3-8 mm in total length were obtained from the eastern Indian Ocean off north-western Australia in the southern summer. In addition, a single dubious specimen of 4.5 mm in the length was taken at latitude 21°S, longitude 156°E in the southwestern Pacific (Ueyanagi, 1969)
Juvenile stage	Adult number of fin rays	
Young stage	Body shape as adult. Australian catch comprises the youngs of 30-110 cm in fork length, one to five years old (Robins, 1962)	Youngs and immatures are occasionally taken by trolling in the waters along New Zealand (McKenzie, 1961) Probably distributed on whole of the continental shelf of Australia
Immature stage	Japanese catch comprises the immatures of 100-140 cm in the length, four to seven years old (Shingu, 1967)	Exploited widely in the West Wind Drift and related waters between Chile and South Africa. Major fishing grounds so far known are: waters off southeastern Australia, April to October; off New Zealand, the same; southern Australia, September to March; western Indian Ocean, the same; and west of South Africa, year round (Shingu, 1967, MS; Shingu and Hisada, MS, Warashina, MS)

Developmental stage and yearly cycle of life		Major morphological features	Known fishing or sampling areas and seasons
Adult stage: Feeding phase	Japanese catch comprises adults of 140–190 cm in fork length seven to fourteen years old (Shingu, 1967)	Fatty body and beautiful meat (Warashina, 1968; Warashina and Hisada, MS)	Feeding adults are taken widely in the West Wind Drift and related waters. Major fishing grounds for the adults are quite the same with those for the immatures. But the feeding adults are more abundant in high latitude waters than the immatures and spawning adults (Shingu, 1967, MS; Shingu and Hisada, MS, Warashina, 1968; Warashina and Hisada, MS)
Pre-spawning phase		Fatty body, fading meat and advancing gonads (Warashina, 1968; Warashina and Hisada, MS, Shingu, MS)	Waters along western Australia, August to October. The pre-spawning adults seem to migrate east of latitude 110°E (Shingu, MS, Warashina, 1968; Warashina and Hisada, MS)
Mid-spawning phase		Seldom captured by longline. Probably lean body, dark meat and advanced gonads (Shingu, 1967, MS; Warashina, 1968; Warashina and Hisada, MS)	Eastern Indian Ocean off northwestern Australia, October to March. Hook rate in the spawning ground lowers in November to January, surmised as the mid-spawning season (Mimura and Warashina, 1962; Shingu, 1967, MS)
Post-spawning phase		Lean body and dark meat (Shingu, MS, Warashina, 1968; Warashina and Hisada, MS)	Waters along western Australia, December to March. The post-spawning adults seem to migrate west of longitude 110°E. The spents are also taken in the West Wind Drift during December to June (Shingu, MS, Warashina, 1968; Warashina and Hisada, MS)

Developmental stage and yearly cycle of life	Abiotic factors of habitat		
	Water mass	Submarine topography	Temperature and salinity at surface
Egg stage	Probably the transitional zone between the Sub-tropical and Tropical Zones by Rochford (1962)		
Pre-larval stage			
Post-larval stage	Transitional zone between the Sub-tropical and Tropical Zones defined as such by Rochford (1962)		Temperature ranged 28°C to 30°C at successive stations, except one of 24.7°C (Ueyanagi, 1969)
Juvenile stage			
Young stage	Northern edge of West Wind Drift (Shingu, MS)	Continental shelf	In the Australian waters, 16°C to 20°C, and 34.8‰ to 35.9‰
Immature stage	West Wind Drift and its northward branches (Shingu, 1967, MS)	Aggregate in the vicinity of continent, islands and banks, although migrate in wide ranges of oceans	In the waters around eastern Australia, 14°C to 19°C and 35.0‰ to 37.0‰ for northward migration period of May to October, and 5°C to 15°C and 34.0‰ to 35.5‰ for southward migration period of November to April

Developmental stage and yearly cycle of life		Abiotic factors of habitat: Water mass	Abiotic factors of habitat: Submarine topography	Abiotic factors of habitat: Temperature and salinity at surface
Adult stage	Feeding phase	West Wind Drift and its northward branches (Shingu, 1967, MS; Warashina, 1968; Warashina and Hisada, MS)	Aggregate in the vicinity of continents, islands and submarine bancs, although migrate within wide range of oceans	Mainly $8^{\circ}C$ to $15^{\circ}C$
	Pre-spawning phase	West Australian Current (Shingu, MS; Warashina and Hisada, MS)		Attracted to high temperature over $20^{\circ}C$
	Mid-spawning phase	Transitional zone between the Subtropical and Tropical Zones by Rochford (1962)		In northern part, north of latitude $20^{\circ}S$, $24^{\circ}C$ to $30^{\circ}C$, and 34.0% to 35.0%, and in southern part, south of latitude $20^{\circ}S$, $17^{\circ}C$ to $25^{\circ}C$ (Shingu, MS)
	Post-spawning phase	Southward branch of equatorial current along western coast of Australia and West Wind Drift (Shingu, 1967, MS; Warashina, 1968; Warashina and Hisada, MS)		Attracted to low temperature below $15^{\circ}C$

APPENDIX II

STANDARDIZATION OF OBSERVATIONS MADE DURING EXPLORATORY OR EXPERIMENTAL FISHING IN THE MEDITERRANEAN

I. FISHING GEAR CLASSIFICATION

Trawls

- Bottom trawls
  - with beam – single rig
    - double rig
  - with otterboards – single rig
    - double rig
  - with two boats (bottom pair trawl)
- High opening bottom trawls or semi-pelagic trawls
  - with otterboards
  - with two boats (semi-pelagic pair trawl)
- Pelagic trawls
  - with otterboards
  - with two boats (pelagic pair trawl)

Seines

- Purse seines
  - one boat fishing
  - two boat fishing
- Lamparas
- Beach seines
- Danish seines

Gillnets

- Driftnet
- Bottom-set gillnets

Liftnets

- Liftnets on shore
- Liftnets on boat

Trapnets (including madragues)

Lines

- Handlines
- Pole lines
- Trolling lines
- Bottom longlines
- Floating longlines

Pots or traps

Dredges

II. SPECIFICATIONS OF GEAR AND FISHING EFFORT

Trawls

- Type and characteristics of the trawl: length of headlines and ground-rope, circumference at lower bosom level, number of constitutive panels, twine material and strength, mesh sizes of the net sections and especially of the codend (specify the measuring method), type of braiding, mesh size of liners and covers, opening height and spread between door and wing tips.

- Characteristics of the main parts of the rigging: warps, otterboards, sweeplines, floats, ground-rope and weights.

- Fishing time, duration of tow: from the time the net reaches bottom and begins fishing until the beginning of the lifting operation.

- The trawling speed should also be recorded.

- Pull on the warps.

Seines

- Specifications of the seine: lengths of floatline and leadline, stretched depth the net, hanging ratio of the ropes*, mesh sizes of the net and its bunt, type of material and strength, weight on leadline in kg/m.

- Purse line and tow line specifications.

- Seining method: use of light or bait to attract and concentrate fish.

- Geographic position.

- Fishing time: record active searching time between sets and the duration of the net setting and hauling operation.

Gillnets and trammels

- Specifications of the net: lengths of floatline and leadline, stretched depth of the net, mesh size, hanging ratio on ropes, type of material, thread diameter, colour, numbers and weights of sinkers.

- Immersion depth.

- Fishing time: duration of fishing operation from the time the net is set until the beginning of hauling.

Liftnets

- Net specifications: dimensions of frame, mesh size, twine material and strength etc.

- Use of light or bait.

- Geographic position or location.

- Duration of one fishing operation.

* Hanging ratio according to ISO recommendations: length of rope/length of stretched netting x 100.

Trapnets and madragues

- Specifications of the traps: description of shape and dimensions including length of main and auxiliary leaders, number and arrangement of trap chambers, orientation in relation to the shore, materials, and mesh sizes, etc.

- Fishing time: the time interval between the successive emptying operations.

Lines

- Gear specification: number of lines in use, length of the main line, interval and length of branch lines, materials used for construction of the different elements including type of bait or lures, type and number of hooks, record immersion level (floating longlines) or distance to the bottom (midwater longlines).

- Fishing time: record interval from the completion of the baiting operation to the start of the hauling operation, record the average time to bait and set lines.

Pots

- Gear specification: type, dimensions, materials, mesh size or free intervals, weights, dimension of escape hatches, type of bait, number of pots, distance between pots on a line, number of lines.

- Fishing time: record the number of hours between the completion of the setting operation and the start of the hauling operation, also record the average time of the baiting setting operation.

Dredges

- Gear specification: type, design, dimensions, materials, mesh size or free intervals, weight or other sinking device, towing method.

- Fishing time: from the end of shooting to the beginning of hauling.

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FT/T41	Manual of methods for fish stock assessment - Part III Selectivity of fishing gear	January 1966
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	Manuel sur les méthodes d'évaluation des stocks ichtyologiques - IVe partie - Le marquage	
	Manual de métodos para la evaluación de los stocks de peces - Parte IV - Marcado	April 1966
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	Manual de métodos para la evaluación de los stocks de peces - Parte II - Tablas de funciones de rendimiento	September 1966
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A printed English version of " Manual of field methods in fisheries biology, provisional edition " was issued in 1960, as a revision of

FB/58/T1	A manual of field methods in fisheries biology (Preliminary draft)	September 1958

Drafts of " Manual of laboratory methods in fisheries biology " were issued as

FB/58/T3	Part I - Physical and chemical methods in meteorology and oceanography	January 1958
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